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THIRD REPORT TO CONGRESS

RESOURCE RECOVERY and WASTE REDUCTION

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FOREWORD

The Solid Waste Disposal Act (P.L. 89-272, Title II, Section 205) requires that the U.S. Environmental Protection Agency study the recovery of resources from solid waste and the reduction of solid waste at its sources. This document represents the Agency's third report to the President and the Congress on these subjects; the previous reports were issued in February 1973 and March 1974.

This report reviews the current status of resource recovery and waste reduction in the United States and findings of EPA studies and investigations that have become available over the past year. It reflects the widening interest and knowledge that are developing in these areas, as well as the various unknowns, uncertainties, and barriers that remain.

In view of the rising level of concern about reserves of energy and materials, about the need to restrain our impacts on the environment, and about the growing costs of solid waste management, it seems clear that resource recovery and waste reduction should be matters of ever-increasing priority in the years ahead.

–RUSSELL E. TRAIN
Administrator
U.S. Environmental Protection Agency

CONTRIBUTING STAFF

The information in this report was derived from a number of contractual efforts, demonstration grants, and staff analyses. Contributing EPA staff, under the direction of J. Nicholas Humber, included Stephen A. Lingle, Frank A. Smith, Fred L. Smith, Yvonne M. Garbe, and Penelope Hansen, *Materials Recovery;* Robert A. Lowe, Steven J. Levy, David B. Sussman, and J. Robert Holloway, *Energy Recovery;* Eileen Claussen, Michael Loube, Harold Samtur, and Charles Peterson, *Waste Reduction.* The manuscript was edited by Emily Sano and typed by Nancy Zeigler, Maryellyn Bailey, Jacqualine Donaldson, and Sharon Brady.

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SUMMARY

This report, on the recovery of resources from waste and the reduction of waste generation, examines the policy issues, reviews technological progress, summarizes city and State activities, and reviews EPA studies and investigations for the year 1974. The following is a chapter-by-chapter summary of the report.

BACKGROUND AND PERSPECTIVES ON RESOURCE RECOVERY AND WASTE REDUCTION

Both resource recovery and waste reduction are important waste management techniques because they reduce the amount of waste discarded, thus reducing collection and disposal costs. Both are also measures to conserve natural resources and prevent environmental damage.

Definitions and Potentials

- *Source separation (the separating out of recyclable material at the waste source) has been the principal method of recovery to date.* Approximately 9 million tons of materials, mostly paper, were recovered in 1973. Although the yearly amount is expected to increase to between 15 and 17 million tons by 1985, it appears that potential recycling levels, which are much higher, will not be realized.
- *Technology for resource recovery from mixed wastes is still in the development stage.* Some technologies have been demonstrated; many have not. Existing commitments for plant construction indicate that many systems will be demonstrated in the next 3 to 5 years. Very little can be done to accelerate this progress because of time required for proper planning, design, construction, and shakedown. It appears that by 1985 about 10 percent of the nation's residential and commercial waste will be processed by resource recovery plants. The potential level, however, is 50 to 60 percent.
- *Primary obstacles to resource recovery are weaknesses in the markets for secondary materials, and institutional shortcomings.*
- *Waste reduction techniques could reduce waste generation by more than 20 million tons a year by 1985.* These techniques involve the redesigning of products or changes in societal patterns of consumption and waste generation. A 20-million-ton reduction would represent 15 percent of nonfood product wastes. Total post-consumer waste, including food and yard waste, would be reduced by more than 10 percent.

Post-Consumer Solid Waste Generation Estimates for 1973 and Projections

- *Half of recent increases in waste generation was contributed by containers and packaging.* According to material flow estimates, total residential

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and commercial waste generation increased from 125 million tons in 1971 to 135 million tons in 1973.

- *Only 7 percent of post-consumer waste (other than junked autos) was recycled in 1973.* Most of the recycling (93 percent of total tonnage) is accounted for by paper products–principally old newspapers, office papers, and paperboard packaging.
- *Even with projected increases in resource recovery, the amount of solid waste disposed of annually will increase by 30 million tons by 1985.* A quadrupling in recovery of materials and energy is projected, but wastes disposed of will still increase in the absence of new Federal incentives for resource recovery and waste reduction.

Significance of Resource Recovery and Waste Reduction

- *Both approaches are necessary to have a positive impact on the amounts of solid waste disposed of.* The philosophical debate between resource recovery and waste reduction is not valid. Neither approach by itself will yield desired reductions in waste levels and solid waste management costs.
- *Resource recovery and waste reduction could make substantial contributions to conservation of raw materials and energy.* U.S. and foreign growth rates in material consumption suggest that the world's natural resources base will be subject to extreme pressures before the end of this century; conservation measures seem imperative.
- *The environmental implications of these approaches extend far beyond the local incinerator or dump site, since they are inextricably linked to the industrial structure of the economy.* Whenever a waste reduction measure reduces the quantity of a material consumed, the quantities of all direct and indirect raw material and energy inputs–and their associated environmental impacts–are also reduced. Resource recovery has similar implications: the environmental effects of manufacturing using secondary materials are almost always less than those of manufacturing from virgin materials.

WASTE REDUCTION

Waste reduction is defined here as reduction in the *generation* of waste through a reduction in consumption of materials or products.

Technical Options

The major technical options in achieving waste reduction are:

- *Reduced resource use per product*–the designing of products so that minimal quantities of resources are used in their construction (e.g., a thinner-walled container). This would result in a decrease not only in the amount of materials used but also in energy consumption. Increasing costs of materials and energy have resulted in new designs to reduce resource intensiveness in products such as steel cans, glass bottles, shipping containers, and milk containers.
- *Increased product lifetime*–the use of products over an extended period of time (e.g., use of a tire with a longer service life) and the designing of products for longer life. The availability and use of products with longer lifetimes would clearly impact upon the waste stream. As product life increases, solid waste generation per unit of time for the product decreases. It should be

noted that product lifetime is a relatively complex attribute of durable goods, depending not only on durability but also on sociological and economic factors.

- *Product reuse*–the multiple use of products in their original forms (e.g., the use, washing, and refilling of a glass bottle) and the designing of products for multiple use. Product reuse has significant impacts upon litter, material and energy consumption, and waste generation. The concept applies to the broad and increasing category of products that are now designed to be used once and discarded. Reuse is different from recycling in that the products are not reprocessed and refabricated but are used in their original form. Studies of refillable beverage containers indicate that considerable savings in materials and energy and reduction in waste generation can be achieved through use of such products.

Public Policy Options

- *Voluntary waste reduction*–voluntary shifts in product design and in consumer choices to reduce resource use and waste generation. Industries could redesign their products to conserve resources and reduce waste, and consumers can make purchases after considering the implications for resources and waste of available product choices.

Voluntary programs seem to hold more promise than mandatory programs, particularly at a time when there is a confluence of business, environmental, and consumer interests in the area of product design. EPA is now actively urging voluntary waste reduction and has established a program designed to focus industry efforts on product redesign for decreased material use.

- *Deposits*–systems designed to provide an incentive for the reuse of products. Deposits could apply to reusable products (e.g., refillable soft drink bottles or tires) or to other items that could be returned for recycling (e.g., a deposit on automobiles to decrease auto abandonment). Implementation of a deposit system would provide an economic incentive to return a product to a central collection point so that it could be reused with minimal recovery costs. An economic disincentive would also be imposed on those who do not return the product.

A great deal of public attention has been focused on deposit systems for beer and soft drink containers. In *Resource Recovery and Source Reduction; Second Report to Congress*, the impacts of deposit systems were presented in some detail. As is pointed out in that report, a deposit system will likely result in declines in beverage container litter and solid waste. Also, to the extent that the deposit results in a predominantly refillable bottle system, there will be substantial energy, material, and pollution savings.

Cost savings to the consumer are also likely to occur as a result of a shift to a largely refillable bottle system. Beverages sold in refillable containers are cheaper than those sold in one-way containers because cost savings attained through multiple use are greater than cost increases added by container cleaning and transportation.

On the basis of these indications, EPA has testified to the Congress favoring the implementation of a nationwide mandatory deposit law for beverage containers. However, implementation of such legislation, if enacted, should be phased in over a substantial period of time in order to minimize unemployment and other economic dislocations that might result.

- *Product charges*–taxes designed to provide an incentive for decreased material and product use. A study of the cost and effectiveness of product charges in reducing the consumer packaging segment of municipal waste was carried out. Three charge schemes were selected for analysis:

1. A tax on consumer products packaging by weight
2. A tax on the weight of consumer products packaging with an exemption for recycled materials (i.e., a tax only on the weight of virgin materials consumed in a package)
3. A per unit tax on all rigid containers used to package consumer products

The study found that for each tax, the effectiveness increases as the tax rate increases. Comparing the different product taxes, the per unit tax on containers induces the largest reductions in solid waste generation and energy utilization. The product tax on packaging with an exemption for recycled materials leads to substantial increases in the recycling of post-consumer wastes and reduces raw materials consumption. The tax on packaging by weight without the exemption has about the same effectiveness in reducing solid waste generation and energy utilization as the tax with an exemption, but it is substantially less effective in reducing raw materials consumption and less effective in increasing the recycling of post-consumer wastes.

ENERGY RECOVERY FROM POST-CONSUMER SOLID WASTE

In 1973, about 135 million tons of solid waste were generated by residential and commercial sources in the United States. About 70 to 80 percent of that waste was combustible and convertible to energy.

- *Not all waste is available for energy recovery.* Because energy recovery systems must be large to achieve economies of scale, energy recovery appears feasible only in more densely populated areas, such as Standard Metropolitan Statistical Areas (SMSA's).

- *A significant amount of energy can be recovered from municipal waste.* This energy is equivalent to 10 percent of all coal used by electric utilities in 1973 and is enough to light every home and office in the nation.

- *Only 10 percent of the potential will be realized by 1980.* Based on energy recovery systems planned or under development at the present time, it is projected that by 1980 such systems should be operating in almost 30 cities and counties and recovering the equivalent of 40,000 barrels of oil per day, or less than 10 percent of potential.

- *Some technologies are commercially available now.* These include (1) the generation of steam (for district heating and cooling or for industrial processing) in a waterwall incinerator fueled solely by unprocessed solid waste and (2) the use of prepared (shredded and classified) solid waste as a supplement to pulverized coal in electric utility boilers. Steam generation systems are being built in Nashville, Tennessee (for district heating and cooling), and in Saugus, Massachusetts (for industrial process steam). The use of prepared solid waste as a supplementary boiler fuel is being demonstrated with EPA grant support in St. Louis, Missouri, with the cooperation of and funding by the Union Electric

Company. Supplementary fuel systems are also being implemented by many communities across the country.

- *Although technology is available, some risk exists because the operating experience has not been substantial.* These technologies are defined as commercially available because they have been demonstrated in large-scale facilities and because private industry is offering the systems for sale. However, there has been relatively little experience with these systems. Consequently, until more of them are built and operated, there will still be some risk associated with their implementation.

- *Other, and possibly more economical and more efficient, technologies are being developed.* Pyrolysis, which converts solid waste into gaseous or liquid fuels, is being demonstrated with EPA support in Baltimore, Maryland, and San Diego County, California, and by several private companies. Pyrolysis systems are projected to become commercially available in the 1977 to 1980 time period.

In addition to pyrolysis, the production of methane gas through controlled biological decomposition (anaerobic digestion) of solid waste is about to be performed at pilot-plant scale. Commercial implementation of this technology is projected to begin after 1980.

MATERIALS RECOVERY

Paper Recycling

- *In 1973 the amount of wastepaper recycled domestically was 21 percent of total paper and board consumption.* However, of all post-consumer paper discarded into the municipal solid waste stream, only 16 percent was recycled. Both of these figures represent slight increases over 1972.

- *Wastepaper recycling (14 million tons) could easily have been doubled by expanding the practice of source separation.* There were 44.2 million tons of post-consumer paper discards unrecovered in 1973, including 8 million tons of newspapers, almost 12 million tons of corrugated containers, just under 10 million tons of printing and writing papers, and almost 15 million tons of other grades.

- *Wastepaper prices fluctuated widely in the last 2 years.* The demand for wastepaper took a significant turn upward during 1973 and early 1974, then reversed itself and has dropped severely from mid-1974 through the first quarter of 1975. By late 1974, wastepaper prices had fallen to one-half to one-fourth the levels of only 6 to 9 months earlier.

- *Exports of wastepaper increased significantly in 1973.* They increased by 65 percent over 1972, but still represented only about 5 percent of total recovery of wastepaper in the United States. In 1974 wastepaper exports continued to increase, and by midyear were double the corresponding level of 1973. However, in the latter half of 1974 exports declined rapidly. Total exports for 1974 were 91 percent above those of 1973.

- *Future trends in wastepaper demand are unclear.* Industry projections for 1974 through 1976 had suggested wastepaper consumption increases of roughly 6 percent per year, but consumption actually fell slightly in 1974. Even if the projections were realized, however, the recycling rate would have been increased only slightly, if at all.

- *Source separation of wastepaper is the most prominent means of recovering paper from municipal discards.* In September 1974 there were approximately 134 programs for separation of newspaper by homeowners for subsequent collection on a regular basis. Only a dozen such programs existed in 1972. Source separation of corrugated containers and office paper also grew rapidly in 1973. At least 200 office paper separation programs have been initiated since the beginning of 1973.

- *Source separation can reduce waste management costs.* Data on the economics of separate newspaper collection programs from case studies show that many communities have broken even or achieved savings in their overall collection operation by instituting separate collection. Program economics vary with wastepaper price, disposal costs, type of collection used, and other factors.

Steel, Aluminum, and Glass Recycling–1973

- *Less than 2 percent of the steel scrap (excluding autos) was recovered.* The technology of ferrous scrap recovery is well developed. Economics appear favorable when shredding of waste is not being performed exclusively for ferrous recovery and when markets are available within a reasonable distance. EPA is aware of 25 cities that are magnetically separating ferrous metal. The major markets for recovered ferrous scrap include the copper precipitation industry, the steel industry, and the detinning industry. Currently, more than half the scrap is consumed by the copper industry.

- *About 3 percent of the glass was recovered, mainly through volunteer collection centers.*

- *The technology for glass recovery from mixed wastes has not been demonstrated at full scale.* The technical and economic feasibility is as yet uncertain. Technically, color-mixed glass can be obtained more easily and cheaply than color-sorted glass, but markets are less plentiful. However, new potential markets exist for color-mixed cullet, such as in foamed glass insulation and in the making of bricks. These markets have not yet been developed significantly.

- *About 3.5 percent of the aluminum in the municipal solid waste stream was recovered, primarily through collection centers.*

- *No technologies to recover aluminum from mixed waste have been demonstrated at full scale.* Several new mechanical techniques are being developed, but their technical and economic viability is still uncertain. Because of its high value, the recovered aluminum is not expected to pose any significant marketing problems.

RESOURCE RECOVERY PLANT COST ESTIMATES

The Environmental Protection Agency has analyzed a number of engineering design conceptions for the next generation of shredded fuel recovery plants based on the St. Louis prototype. Existing cost estimates prepared by engineering consultant and system development companies are not directly comparable with one another because of differences in estimating methods, accounting formats, and location-specific costing factors. Therefore, five recent preliminary design cost studies were normalized to produce comparable cost estimates representative of the degree of consensus within the engineering community.

The results indicate that differences in cost estimates among design conceptions and engineering firms are still quite significant, even after adjustments for location, time, and other nonstandard elements. However, the differences are no greater than might be expected given the present state of technological development and lack of operating commercial prototypes. Indeed, differences in basic capital and operating costs attributable to different technical engineering conceptions are in many respects of less consequence than the differences introduced by the use of alternative costing methods and location-specific cost factors.

Analysis of normalized cost estimates and alternative product selling-price projections indicates that potential net cost projections will fall in a very broad range from a net profit (very unlikely) to a very high cost (also unlikely). Most cases appear competitive with current or projected landfill costs in many, if not most, U.S. cities. All cases using low-cost (public sector) financing options, including even the highest cost case-study plant, were competitive with conventional municipal incineration.

Three conclusions of the analysis are of special importance:

- *Shredded fuel revenues are a major element in determining net cost; differences between high and low estimates of these revenues are considerable.* The potential market value of the shredded fuel is the most uncertain element of the net cost equation. The high and low estimates of shredded fuel price are $16 and $3 per ton of raw waste processed. The range between the estimates almost dwarfs all other elements of the net cost calculation.
- *High utilization of plant is necessary to prevent operating cost escalations.* Reduction in utilization from 90 percent to 60 percent can result in operating cost increases of up to $4 per ton. This is substantial for systems that are projected to operate at net costs of $6 to $10 per ton. This high cost of failure to maintain reasonable utilization rates underlines the importance of sound planning and capable management.
- *The cumulative importance of "other special costs" elements must not be discounted.* This major category of costs includes property taxes, land and unusual site work, residual disposal, fuel transportation, and non-plant overhead charges. The "other special costs" can be higher than either of the other two major cost categories, capital costs and operating and maintenance costs.

STATUS OF WASTE REDUCTION AND RESOURCE RECOVERY EFFORTS

Waste Reduction

- *Industry activity.* Resource shortages and inflation have forced many industries to take steps that provide waste reduction benefits. Many have reduced the variety of products (e.g., number of different container sizes offered) that they manufacture or have redesigned products to use less material. It is expected that industry will continue to redesign products if shortages and price increases continue. It is significant that these product design shifts are now becoming a requirement among product designers and marketers; that is, resource use is now a high-priority consideration in the manufacture of a product. Once this direction is firmly established, the impacts upon resource use, environmental pollution, and waste generation can only be positive.

- *State activity.* Packaging control legislation has been introduced in 50 State legislatures and numerous county and city councils since 1971. As of October 1974, three States (Oregon, Vermont, and South Dakota) have passed laws relating strictly to beverage containers; and one State (Minnesota) has passed a law that affects all major littered items.
- *Citizen activity.* Basing their appeal upon both resource conservation and solid waste management needs, citizen groups and spokesmen for the public interest have consistently called for a national effort to decrease the quantity of wastes generated.

Resource Recovery

- *State activity.* As of the end of 1974, 10 States had grant or loan programs for the construction of resource recovery systems; 12 States are involved in planning or regulating resource recovery activities on a statewide basis; and 5 States have the authority to create agencies to operate resource recovery facilities. In this last group, the Connecticut Resource Recovery Authority is the only agency that has been funded and has committed funds to construction.
- *Municipal activity.* Resource recovery systems are operating in five cities around the country; seven other plants are under construction or in the startup phase; approximately 20 communities are committed to building systems, and at least 30 others are active in evaluating the feasibility of resource recovery.

This level of activity is substantial considering the low level of experience with resource recovery technologies. As experience broadens and more operational data become available, implementation should continue at a reasonable rate.

Constraints to Resource Recovery

Implementation could be accelerated if certain constraints were overcome. The major constraints include:

- *Technical risks.* The technical risks include uncertainties about costs and operating performance. Additional operational experience providing necessary data will reduce these uncertainties. The present level of implementations should provide sufficient data.
- *Marketing risks.* Virtually no cities or companies have substantial experience in the marketing of energy and secondary materials extracted from municipal solid waste. Long-term purchase commitments are requisite to minimizing revenue uncertainties. However, because there is little experience with products recovered from municipal waste, few prospective purchasers are willing to make long-term commitments. Again, this constraint can be reduced by additional experience.
- *Inadequate information.* This is an impediment to any decisionmaking process. Comprehensive information is not available. A stronger Federal technical assistance program can develop from systems being constructed.
- *State laws.* There are a variety of State laws that could delay or jeopardize the future implementation of resource recovery systems. Three examples are laws restricting contract length, laws requiring "split bidding," and laws that require selection of a contractor on the basis of cost alone.

SUMMARY

Financing Resource Recovery

- *Financing does not appear to be a problem.* To date, financing has not been a problem for well-conceived systems. Most of the focus in plant financing has been on the public and private bond markets: municipal general obligation bonds, municipal and industrial revenue bonds, and corporate bonds. Public financing is more attractive than private financing to most cities because of lower interest rates.

The capital markets have limited experience with resource recovery systems. More experience and information development must occur to improve the knowledge of the financial community.

In summary, most constraints can be overcome by additional experience and information, and a strong Federal program to develop information and provide technical assistance.

Chapter 1

BACKGROUND AND PERSPECTIVES ON RESOURCE RECOVERY AND WASTE REDUCTION

Resource recovery and waste reduction can be thought of as waste management techniques since both reduce the amount of waste discarded. From a slightly different viewpoint, these nondisposal waste management alternatives can be regarded also as natural resource conservation and environmental protection measures because they save material resources and reduce the causes of environmental degradation. The purposes of this chapter are to provide background information relevant to resource recovery and waste reduction and to discuss their potential significance in relation to this country's interrelated waste management, resource conservation, and environmental protection problems.

DEFINITIONS AND POTENTIALS

Post-Consumer Solid Wastes Defined

Like the first two reports, this *Third Report to Congress* is focused on that portion of the nation's total solid waste stream referred to as "post-consumer" municipal solid wastes, i.e., those discarded by the final consumer, not by raw-material producers and manufacturers. These include both the bulky and non-bulky wastes typically collected in household refuse, as well as similar materials from commercial and governmental office buildings, wholesale and retail trade establishments, and other general business and service sectors of the economy.

Specifically excluded from the present definition are wastes from "pre-consumer" sources, such as mining, agricultural, and industrial processing residuals, as well as a number of waste types that are often considered to be in the municipal or post-consumer category, such as demolition and construction wastes, street sweepings, and sewage sludge.

Detailed estimates of the quantity and composition of the post-consumer municipal solid waste stream are presented later in this chapter.

Resource Recovery

"Resource recovery" is a general term encompassing a wide variety of technical approaches for retrieving or creating economic values from waste streams. In the solid waste management context, resource recovery can be defined to include three main categories:

1. *Material recycling*—the recovery of specific reprocessed secondary materials, such as new steel from steel scrap or new paper products from wastepaper.
2. *Material conversion*—the recovery from waste of new forms of byproduct-type materials, typically for uses very different from that of the original material. Well-known examples include the production of highway paving materials out of waste glass and rubber, building bricks from incinerator residues, and compost from mixed organic materials.
3. *Energy conversion*—the recovery of energy values, either directly by burning combustible waste in a boiler to produce steam or hot water, or indirectly by first processing the organic waste fraction to produce a solid, liquid, or gaseous fuel.

Resource recovery from municipal solid waste invariably requires a sequence of collection and processing steps to render the recovered products available in a form, quantity, and location that would make them economically competitive with counterpart "virgin" products. The initial stages of this sequence are analogous to the extraction and preliminary processing phases for virgin materials, including the mining of ores and harvesting of crops, as well as the initial refining stages.

In the case of recovery from wastes, the "extraction" phase may be accomplished in either of two ways. One is the traditional method of "source separation"–i.e., the segregation of specific waste products at their point of discard for concentrated collection. The other is the newly evolving mixed-waste processing approach whereby municipal solid waste collected in mixed form is processed to yield secondary material or energy products.

Regardless of which "extraction" method is involved–source separation or mixed-waste processing–the recovered material or energy product must still be marketed in competition with a virgin raw material or fuel.

Source Separation. Segregation of waste materials at the point of discard has been the principal method for recovering materials from the waste stream for recycling. Source separation currently accounts for virtually all post-consumer recycling, estimated at about 9 million tons (of which 8.7 million tons was paper) in 1973. This amounted to about 10 percent of gross discards of nonfood product waste.

Relevance. Source separation is applicable to a variety of products and materials, including at least the following: glass and metal containers, various types of wastepapers, tires, large household appliances, and waste lubricating oils. These types of wastes account for about 75 percent of post-consumer gross discards of manufactured products, or about 50 percent of total waste, including food and yard sources.

Source separation as a means of recycling has a number of apparent strengths. For example, it is feasible at a small scale and is thus available to smaller cities. Since it has very low capital requirements, it is a flexible option that can be phased in rapidly and modified readily over time. It also has a technical advantage in that it produces relatively "pure" (uncontaminated and homogeneous) products which can have relatively high value.

There are also well-recognized limitations or shortcomings. Source separation requires direct participation by large numbers of people (i.e., in households, office buildings, and retail stores). Historically its effectiveness has been mixed due to lack of organization and incentives. Its economic feasibility is adversely affected by fluctuating market prices, particularly for paper and ferrous scrap. On a national and regional basis, short-run future market demand is distinctly limited relative to *potential* levels of supply. This is particularly true for wastepaper (almost all grades), tires, and probably waste lubricants, under current and projected economic conditions. Demand for steel cans is also limited in most regions. Demand for other types of household ferrous scrap is uncertain.

Potentials. In the absence of major Federal initiatives, recycling through source separation is projected to increase from about 9.4 million tons in 1973 to 16.5 million tons by 1985, according to EPA estimates based on work by the Midwest Research Institute. Although this indicates modest increases in the recycling rates for most materials, they would still fall far short of potentials.

Though often considered a purely "voluntary" approach because of its association with local "recycling centers," most source separation, in fact, takes place at commercial establishments as part of routine business activity, for profit. Another large source separation component, newspapers from households, is undertaken for profit by fund-raising charities and private scavengers. Precisely how large a portion of specific waste fractions could be extracted under various possible local or national incentive programs is not known. Present EPA estimates, which are crude and represent only a first approximation, indicate that maximum potential source separation may be about triple the level projected for 1985.

Based on expected amounts in the waste stream of wastepaper, glass and metal containers, tires, and major household appliances, it is estimated that almost 50 million tons a year could be source separated for recycling or material conversion by 1985 under a strong program of incentives. This 50-million-ton potential should be compared with the roughly 17 million tons actually projected for that year, and the 9 million tons estimated for 1973. As a "supply side" option for resource recovery, source separation thus appears to have a great deal of unused potential–upwards of 30 million tons per year over and above projected rates by 1985. A 30-million-ton increment would amount to 20 to 25 percent of the recyclable material in the waste stream.

With the possible exception of aluminum, the primary constraint on significantly increasing the recycling rates of metals, fiber, and rubber by source separation is lack of industrial demand for secondary materials. However, much could also be done to improve the supply side–that is, the effectiveness of source separation systems. In principle, source separation is potentially subject to a variety of incentives at various levels of government. In terms of technique and management, very little broad-scale (citywide or countywide) experience exists, and very little serious study has been directed to the development of multiproduct source separation systems, including the use of incentives to improve either supply or demand.

Mixed-Waste Processing. Mixed-waste processing includes a variety of technologies for separating or converting mixed municipal refuse into useful materials or energy. All such systems are presently in an early, experimental stage of development, although many of their component parts are standard items.

Relevance. Virtually all such systems extract ferrous metals, with up to 95-percent extraction efficiency. All systems could include optional extraction of some kinds of paper by handpicking, depending on economics. Systems based on wet-pulping (like the Black Clawson plant in Franklin, Ohio) and dry-shredding with air classification (St. Louis) are both adaptable in principle to either fiber recovery or energy conversion. However, little interest has been shown on the part of the U.S. paper industry thus far, and most proposed installations are directed at some type of energy market. Components for the recovery of glass and nonferrous metals are also optional for most systems.

Large-scale mixed-waste processing for resource recovery is compatible with existing waste collection and transfer systems. For the region served, such plants could separate or convert very large fractions of total post-consumer waste. Most engineering design estimates suggest that over 80 percent by weight and over 90 percent by volume of the waste input can be diverted from disposal by these types of systems. On the other hand, such enterprises involve relatively large initial capital requirements and long-term commitments. To some extent, they also share the future market uncertainties of source separation.

Potentials. It is not clear how rapidly resource recovery plants would be introduced in the absence of strong Federal incentives or what the precise timing would be. There are simply too many major variables involved, not the least of which is the uncertainty of the competing technologies. Various estimates range from 15 to 40 plants, averaging 1,000 tons per day, on line for 1980. Midwest Research Institute has recently projected that 32 installations with an aggregate capacity of 80,000 tons per day (24 million tons per year) would be on line by 1985; this was given as the most likely estimate within a range of 20 to 50 plants (50,000- to 130,000-TPD capacity).[1] This 1985 projection has been taken as a baseline for present purposes.

On the basis of this projection and an average recovery rate of 85 percent of raw waste processed, a total of about 20 million tons of recyclable materials and fuels would be recovered in 1985. This would be about 11 percent of the waste generation projected for the nation as a whole, and less than 50 percent of the projected increase in annual solid waste generation between 1973 and 1985. Doubling the projected number of plants to provide a capacity of 160,000 tons per day (48 million tons per year) would, on a nationwide basis, just keep pace with the growth in solid waste generation between 1973 and 1985.

At the extreme, the maximum quantity of waste that could be processed in centralized, mixed-waste facilities is probably limited by collection logistics and economics to waste from the urbanized areas of the country. For 1985, it is estimated that collected waste in U.S. urbanized areas will amount to about 68 percent of total U.S. waste generation. If all of this urban waste were processed at 85 percent efficiency in conversion of material, this would account for about 115 million tons (just under 60 percent of the U.S. solid waste stream) or about five times the MRI baseline projection. This is, of course, totally unrealistic in the 1985 time frame, even assuming maximum Federal intervention. Nevertheless, it is useful to note that even with this maximum conceivable implementation, fully 40 percent of the national waste stream would not be included.

From the national perspective, mixed-waste processing will not be of major quantitative significance by 1980. That is, it seems unlikely that much more than 5 percent of the nation's annual waste could be processed in large-scale plants by that date. However, by 1985, the baseline projection is that about 10 percent of the nation's solid waste stream will be accounted for by mixed-waste systems, even without any new major Federal initiatives. As noted above, this is a relatively small quantity in relation to technological potentials.

Waste Reduction

"Waste reduction" (or "source reduction," the term used in the previous *Reports to Congress*) is prevention of waste at its source, either by redesigning products or by otherwise changing societal patterns of consumption and waste generation.* Three major approaches for reducing solid waste generation have been recognized:

1. *Reducing material per unit of product*–development and use of products that require less material per unit of product or less packaging material per unit of product. Examples could include smaller automobiles in place of larger ones and purchasing small items in bulk quantities in order to reduce packaging requirements.
2. *Increasing product lifetime*–development and use of durable and semidurable goods with greater average lifetime to reduce discards and replacement needs. This approach could be applied to the whole range of durable goods.
3. *Increasing product reuse*–substitution of reusable products for single-use "disposable" products and increasing the number of times items are reused. Examples of items to which this principle could be applied include beverage containers, food service items, and certain napkin and towel products.

These basic approaches may be carried out both through the redesign of products on the part of producers and by substitution among existing products on the part of consumers. Success thus depends not only on the availability of alternative product designs but also on their acceptance by consumers. The latter often requires extensive "support systems," e.g., maintenance and repair facilities for durable goods, second-hand markets for reusable items, specialized collection and storage systems for reusable containers.

Some waste reduction measures may imply reduced standards of living for at least some groups of consumers and reduced incomes for some groups of producers. On the other hand, waste reduction in general could well be regarded simply as sound economics for the society as a whole, since it reduces the national cost of providing a given level of material well-being. It will involve some change in lifestyle and material consumption habits for a substantial segment of the population if it is to be of any consequence in reducing waste flows.

Relevance. As presently understood, some of the attributes of products and their consumption that are of most significance to solid waste generation appear to be single-use rather than multiple-use design, shorter rather than longer product lifetime (durability), larger rather than smaller products, more rather than less packaging material per unit of product, and more rather than fewer units of products consumed per family per year. Historically, these attributes have been "regulated" for all of the many thousands of products primarily by market forces. With the exception of wartime product rationing and material supply controls, the United States has never experienced broad-scale public intervention into these dimensions of our economic life. Currently, the major peacetime examples of intervention relate to product safety and public health considerations.

Although our current understanding is limited, it appears that one or more waste reduction approaches are potentially relevant to virtually all consumer goods (including containers and packaging) entering the solid waste stream. One possible exception is the food products category, although even here one can find examples where the application of plant and animal genetics and various food marketing innovations has altered the generation of food wastes. If one rules out food and yard wastes, this leaves about 60 to 65 percent of the post-consumer solid waste stream which is subject to some degree of waste reduction at the source.

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*The term "waste reduction" should not be confused with "volume reduction," which is used in the solid waste management field to refer to waste compaction or baling.

Many types of waste reduction could be initiated at the Federal level. Since such measures would operate primarily through the product market structure (rather than through waste collection systems), the entire national marketing area of products would be affected, thus reducing rural as well as urban wastes. Many types of waste reduction can be achieved voluntarily, with economic advantages to the industries in question (although not necessarily to their material suppliers). Many types could be introduced relatively rapidly and can thus have nationwide impact in only a very few years' time (certain packaging design changes, for example). In the case of some product design changes, there are no recurring annual operating and maintenance costs, only initial costs for the changeover in the form of capital resource commitments.

Potentials. Waste reduction potentials are extremely difficult to evaluate in quantitative terms. Nevertheless, a scenario has been constructed based on a major national shift to refillable beverage containers and a modest but pervasive program for other nonfood products. Analysis of potential material savings from this combination is based on the following specifics: (1) an 80-percent shift to (18-trip) refillable beer and soft drink containers, with aluminum and steel cans sharing the remaining 20 percent; (2) a major increase in durability of rubber tires based on currently evolving technology; (3) a 10- to 15-percent reduction in the material requirements of other products based on various possible combinations of increased product durability, reuse, and other consumer conservation measures.

The combined annual effects of this scenario result in potential reductions in the 1985 waste stream on the order of greater than 20 million tons of product-related waste materials. This is more than 15 percent of the nonfood waste stream. Total post-consumer waste, including food and yard waste, would be reduced by over 10 percent.

Obviously many questions can be raised about the feasibility of achieving such a scenario, and considerable additional analysis would be required to substantiate these possibilities and evaluate their economic impacts. Nevertheless, the technical assumptions appear reasonably sound as a set of initial values, at least as to general order of magnitude, in view of the fact that they allow a decade for design and implementation and there is some empirical evidence from the Oregon and Vermont beverage container experience and other specific industry product design changes. (See Chapter 2 for further discussion of State-level beverage container legislation and other examples of waste reduction efforts.)

THE QUANTITY AND COMPOSITION OF POST-CONSUMER SOLID WASTE

The *Second Report to Congress* (March 1974) indicated considerable improvement in our knowledge of both total quantity and composition of the nation's post-consumer solid waste stream. For the first time, estimates were presented detailing the composition of the 1971 waste stream both by material and by product type.[1, p. 3] The work done in the year since that report has not provided reasons to reject or significantly alter the bases for the 1971 estimates.[3,4] They have been updated to 1973 and additional details developed on composition by product type, on recycling, and on projections of future trends.

Estimates for 1973

EPA's current estimates for U.S. post-consumer municipal waste for 1973, based on reported material flow statistics for 1973 and earlier years, are presented in Table 1. This table is organized in the same format as the original table for 1971 appearing in the last *Report to Congress*, with all figures updated to 1973 values. The same definitions and similar methods of calculation are used, so the 1973 data are directly comparable to the 1971 estimates.[2] They are preliminary in the sense that they are based in part on industry statistics for 1973 that are still subject to revision by government and trade association sources. The following were the more significant changes between 1971 and 1973 (Table 2):

Total waste generation:

- Total post-consumer municipal waste increased by 10 million tons (8 percent) from 125 to 135 million tons.
- Per capita generation increased from 3.3 to 3.5 pounds per day (6.3-percent growth).

TABLE 1

MATERIAL FLOW ESTIMATES OF RESIDENTIAL AND COMMERCIAL POST-CONSUMER NET SOLID WASTE DISPOSED OF, BY MATERIAL AND PRODUCT CATEGORIES, 1973*†

Material	Product category (In millions of tons, as generated)‡							Totals			
								As-generated weight‡		As-disposed weight§	
	Newspapers, books, magazines	Containers, packaging	Major household appliances	Furniture, furnishings	Clothing, footwear	Food products	Other products	Million tons	Percent	Million tons	Percent
Paper	11.3	23.3	–	tr.	tr.	–	9.6	44.2	32.8	53.4	39.6
Glass	–	12.1	tr.	tr.	–	–	1.1	13.2	9.9	13.4	10.3
Metals	–	6.5	1.9	0.1	tr.	–	4.0	12.5	9.3	12.7	9.9
Ferrous	–	5.6	1.7	tr	–	–	3.7	11.0	8.2		
Aluminum	–	0.8	0.1	tr.	–	–	0.1	1.0	0.7		
Other nonferrous	–	0.1	0.1	tr.	–	–	0.2	0.4	0.3		
Plastics	tr.	3.1	0.1	0.1	0.2	–	1.6	5.0	3.7	5.6	4.1
Rubber and leather	–	tr.		tr.	0.5	–	3.0	3.6	2.7	3.7	2.7
Textiles	tr.	tr.	–	0.6	0.6	–	0.7	1.9	1.4	2.1	1.6
Wood	–	1.9	–	2.5	tr.	–	0.5	4.9	3.6	4.9	3.6
Total nonfood product waste	11.3	46.9	2.1	3.4	1.3		20.5	85.4	63.5	96.0	71.1
Food waste	–	–	–	–	–	22.4	–	22.4	16.6	18.0	13.3
Total product waste	11.3	46.9	2.1	3.4	1.3	22.4	20.5	107.8	80.1	114.0	84.4
Yard waste								25.0	18.5	19.0	14.1
Misc. inorganics								1.9	1.4	2.0	1.5
Total								134.8	100.0	134.8	100.0

*Smith, F. A., and F. L. Smith, Office of Solid Waste Management Programs, Resource Recovery Division. Data revised Dec. 1974.

†Net solid waste disposal defined as net residual material after accounting for recycled materials diverted from waste stream.

‡"As-generated" weight basis refers to an assumed normal moisture content of material in its final use prior to discard, for example: paper at an "air-dry" 7 percent moisture; glass and metals at zero percent.

§"As-disposed" basis assumes moisture transfer among materials in collection and storage, but no net addition or loss of moisture for the aggregate of materials. Based on estimates in: Niessen, W. R., and S. H. Chansky. The nature of refuse. *In* Proceedings; 1970 National Incinerator Conference, Cincinnati, May 17-20, 1970. New York, American Society of Mechanical Engineers. p. 7-8.

TABLE 2
POST-CONSUMER NET SOLID WASTE DISPOSED OF, BY MATERIAL AND PRODUCT CATEGORIES, 1971 and 1973*†

(As-generated wet weight, in millions of tons)

Materials and products	1971	1973	Growth, 1971-73	Percent change
Material composition:				
Paper	39.1	44.2	5.1	13.0
Glass	12.0	13.2	1.2	10.0
Metal	11.8	12.5	0.7	5.9
Ferrous	(10.6)	(11.0)	0.4	3.8
Aluminum	(0.8)	(1.0)	0.2	25.0
Other	(0.4)	(0.4)	0.0	6.0
Plastics	4.2	5.0	0.8	19.0
Rubber and leather	3.3	3.6	0.3	9.0
Textiles	1.8	1.9	0.1	5.5
Wood	4.6	4.9	0.3	6.5
Total nonfood product waste	76.9	85.4	8.5	11.1
Food waste	22.0	22.4	0.4	1.8
Total product waste	98.9	107.8	8.9	9.0
Yard waste	24.1	25.0	0.9	3.7
Miscellaneous inorganics	1.8	1.9	0.1	5.6
Total	124.8	134.8	10.0	8.0
Product composition:				
Newspapers, books, magazines	10.3	11.3	1.0	9.7
Containers and packaging	41.7	46.9	5.2	12.5
Major household appliances	2.1	2.1	0.0	0.0
Furniture and furnishings	3.2	3.4	0.2	6.3
Clothing and footwear	1.2	1.3	0.1	8.3
Other products	18.4	20.5	2.1	11.4
Total nonfood product waste	76.9	85.4	8.5	11.1
Food waste	22.0	22.4	0.4	1.8
Total product waste	98.9	107.8	8.9	9.0
Add: Yard and misc. inorganics	25.9	26.9	1.0	3.9
Total	124.8	134.8	10.0	8.0

*Smith, F. A., and F. L. Smith, Office of Solid Waste Management Programs, Resource Recovery Division. Data revised Dec. 1974.

†Net solid waste disposal defined as net residual material after accounting for recycled materials diverted from waste stream.

Kinds of materials:

- Total nonfood product wastes accounted for most of the growth—8.5 million tons, or a 11.1-percent increase.
- Paper and paperboard wastes were up by 5.1 million tons (13 percent).
- Glass up 1.2 million tons (10 percent).
- Metals up 0.7 million tons (5.9 percent).
- Plastics up 0.8 million tons (19 percent).
- No major waste material decreased in tonnage.

Product categories:

- Containers and packaging wastes increased by 5.2 million tons (12.5 percent) and in 1973 constituted 55 percent of all nonfood product waste and 35 percent of total post-consumer waste. (In 1971 the corresponding percentages were 54 percent and 34 percent, respectively.)
- Waste newspapers, books, and magazines were up by 1.0 million tons (9.7 percent).

In interpreting these growth rates, it should be noted that 1971 was not a very strong year for many products, whereas 1973 was generally a boom year by comparison. Therefore, the growth rates presented in Table 2 should not be used as trends on which to base future projections, either short-term or long-term.

Readers are also cautioned that data in this section relate to nationwide totals; they may prove to be very inaccurate indicators of conditions in any given State or local area.

A much more detailed accounting of product categories has been prepared for this report (Table 3). This yields a considerably clearer picture of how the waste flows originate, which should be particularly useful in analyses of waste reduction and source separation at the national level. In addition, Table 3 estimates the relationships between "gross discards" (total waste generation before recycling or disposal), "material recycled" from post-consumer gross discards, and "net waste disposed of" (final residual waste remaining after material recovery). Table 4 provides similar estimates by material, rather than product, categories.

It should be recognized that the quantities shown here as recycled include only post-consumer residential and commercial wastes recovered from the product sources listed in Table 3. They do not include material recycled from "pre-consumer" industrial processing, fabricating, or converting operations or from certain post-consumer sources such as demolition or junk auto shredding. Thus, the recycling quantities and percentages shown in Tables 3 and 4 will differ from other reported sources and estimates. This is the first time that comprehensive estimates of post-consumer recycling have been developed for all major materials.

Two major conclusions regarding recycling in 1973 can be drawn from Tables 3 and 4. The first is that very little of the post-consumer wastes (excluding automobiles) is currently recycled. Overall, only about 7 percent of total waste or 10 percent of nonfood product waste was diverted from disposal to recycling in 1973. The second conclusion is that most of the recycling (93 percent of total tonnage) is accounted for by paper products–principally old newspapers, office papers, and paperboard packaging. Of the total amount of paper discarded, 16.5 percent was recycled in 1973. For no other material does the recycled percentage amount to as much as 10 percent.

Future Trend Projections

EPA's most recent projections of waste generation rates to 1990 are presented in Table 5. Unlike the simple extrapolations in last year's *Report to Congress*, the new projections are based mainly on a detailed product-by-product analysis.[1] In addition, as with the 1973 estimates, an attempt has been made to project the quantities of waste that will be recycled or otherwise recovered as resources.

The projections are "baseline" figures in the sense that they are based on an assumption of no new intervention by the Federal Government into the solid waste management field via incentives for resource recovery or waste reduction or new regulations on disposal of municipal solid waste. The future projections do assume a continuation of average historical growth rates for national income and gross national product, although not necessarily for individual product categories. Basically, the projections for future years are based on the same type of material flow analysis and historical data sources used to develop EPA's 1971 and 1973 estimates.

Projection of future solid waste generation has never been subject to greater uncertainties than under present conditions of rising material and energy prices and changing international bargaining relationships. It is still too early to judge the extent to which the materials pricing structure has been permanently altered by the recent massive increases in fuel prices, or whether this should significantly affect either the total picture presented in Table 5 or the underlying data components.

The current projection is that total gross discards will increase quite significantly, up to 225 million tons by 1990. Resource recovery–including both recycling and energy conversion–is projected as increasing quite dramatically, but it must be noted that these figures (especially those for 1985 and 1990) represent the least certain numbers in the table since they are based in part on projections of the number of future large-scale waste-processing installations. Thus, these numbers should be taken with great caution, as should the net waste figures derived from them. As a percent of gross discards, the baseline recovery rate is projected to grow from about 7 percent in 1973 to 17 percent in 1985 and 26 percent in 1990.

TABLE 3

POST-CONSUMER RESIDENTIAL AND COMMERCIAL SOLID WASTE GENERATED AND AMOUNTS RECYCLED, BY DETAILED PRODUCT CATEGORY, 1973*

(As-generated wet weight, in thousands of tons)

Product category	Gross discards	Material recycled		Net waste disposed of		
		Quantity	Percent	Quantity	% of total waste	% of nonfood product waste
Durable goods:	14,700	300	2	14,400	11	17
Major appliances	2,200	100	4	2,100	2	2
Furniture, furnishings	3,400	0	0	3,400	3	4
Rubber tires	2,000	200	10	1,800	1	2
Miscellaneous durables	7,100	0	0	7,100	5	8
Nondurable goods, exc. food:	27,930	3,770	13	24,160	18	28
Newspapers	10,400	2,450	24	7,950	6	9
Books, magazines	3,720	330	9	3,390	3	4
Office paper	6,390	990	15	5,400	4	6
Tissue paper, incl. towels	2,320	0	0	2,320	2	3
Paper plates, cups	600	0	0	600	†	1
Other nonpackaging paper	1,300	0	0	1,300	1	2
Clothing, footwear	1,300	0	0	1,300	1	2
Other misc. nondurables	1,900	0	0	1,900	1	2
Containers and packaging:	52,270	5,330	10	46,940	35	55
Glass containers:	12,400	275	2	12,125	9	14
Beer, soft drink	6,100	190	3	5,910	4	7
Wine, liquor	1,970	25	1	1,945	1	2
Food and other	4,330	60	1	4,270	3	5
Steel cans:	5,650	60	1	5,590	4	7
Beer, soft drink	1,550	15	1	1,535	1	2
Food	3,140	35	1	3,105	2	4
Other nonfood	960	10	1	950	1	1
Aluminum:	820	35	4	785	1	1
Beer, soft drink‡	440	30	7	410	†	†
Other cans	50	1	2	45	†	†
Aluminum foil	330	4	1	330	†	†
Paper, paperboard:	28,230	4,960	18	23,270	17	27
Corrugated	15,100	3,290	22	11,810	9	14
Other paperboard	6,925	1,045	15	5,880	4	7
Paper packaging	6,205	625	10	5,580	4	7
Plastics:	3,090	0	0	3,090	2	4
Plastic containers	510	0	0	510	†	1
Other plastic packaging	2,580	0	0	2,580	2	3
Wood packaging	1,900	0	0	1,900	1	2
Other misc. packaging	180	0	0	180	†	†
Total nonfood product waste	94,900	9,400	10	85,500	63	100
Add: Food waste	22,400	0	0	22,400	17	26
Yard waste	25,000	0	0	25,000	19	29
Misc. inorganic wastes	1,900	0	0	1,900	1	2
Total	144,200	9,400	7	134,800	100	158

*Smith, F.A., Office of Solid Waste Management Programs, Resource Recovery Division. Nov. 1974.

†Less than 0.5%.

‡Includes all-aluminum cans and aluminum ends from nonaluminum containers.

TABLE 4
POST-CONSUMER RESIDENTIAL AND COMMERCIAL SOLID WASTE GENERATED AND AMOUNTS RECYCLED, BY TYPE OF MATERIAL, 1973*

(As-generated wet weight, in millions of tons)

Material category	Gross discards	Material recycled†		Net waste disposed of		
		Quantity	Percent	Quantity	% of total waste	% of nonfood product waste
Paper	53.0	8.7	16.5	44.2	32.8	51.8
Glass	13.5	0.3	2.1	13.2	9.9	15.5
Metals	12.7	0.20	1.6	12.5	9.3	14.6
Ferrous	11.2	0.2	1.4	11.0	8.2	12.9
Aluminum	1.0	0.04	4.0	1.0	0.7	1.2
Other nonferrous	0.4	0.0	0.0	0.4	0.3	0.5
Plastics	5.0	0.0	0.0	5.0	3.7	5.9
Rubber	2.8	0.2	7.1	2.6	1.9	3.0
Leather	1.0	0.0	0.0	1.0	0.7	1.2
Textiles	1.9	0.0	0.0	1.9	1.4	2.2
Wood	4.9	0.0	0.0	4.9	3.6	5.7
Total nonfood product waste	94.2	9.4	9.9	85.4	63.4	100.0
Food waste	22.4	0.0	0.0	22.4	16.6	26.2
Yard waste	25.0	0.0	0.0	25.0	18.5	29.3
Misc. inorganic wastes	1.9	0.0	0.0	1.9	1.4	2.2
Total	144.0	9.4	6.5	134.8	100.0	157.8

*Estimates by the Resource Recovery Division, Office of Solid Waste Management Programs.

†Resource recovery in 1973 included only material recycling. Energy recovery accounted for negligible amounts.

TABLE 5
BASELINE ESTIMATES AND PROJECTIONS OF POST-CONSUMER SOLID WASTE GENERATION, RESOURCE RECOVERY, AND DISPOSAL, 1971 TO 1990*

	Estimated		Projected		
	1971	1973	1980	1985	1990
Total gross discards:					
Million tons per year	133	144	175	201	225
Pounds per person per day	3.52	3.75	4.28	4.67	5.00
Less: resources recovered:					
Million tons per year	8	9	19	35	58
Pounds per person per day	0.21	0.23	0.46	0.81	1.29
Equals net waste disposed of:					
Million tons per year	125	135	156	166	167
Pounds per person per day	3.31	3.52	3.81	3.86	3.71

*Office of Solid Waste Management Programs, Resource Recovery Division. Data revised Dec. 1974. Projections for 1980 to 1990 based in part on contract work by Midwest Research Institute.

The amount of net waste is shown as growing at a decreasing rate to 1985, and then essentially leveling off as the increase in recovery equals the increment of gross discards.

Even at this point, however, the nation still would be faced with disposing of an annual aggregate post-consumer waste load about 30 million tons (23 percent) greater than at present. This increase is projected to occur even with resource recovery tonnage quadrupling by 1985 and increasing by more than sixfold by 1990.

THE BENEFITS OF RESOURCE RECOVERY AND WASTE REDUCTION

An increase in resource recovery and waste reduction would have a positive impact on a number of recognized national problems. Among these are problems relating to community solid waste management, the conservation of scarce material and energy resources, international trade and balance of payments, and environmental protection. For the most part, however, potential benefit relationships are still very poorly understood, both in conceptual and quantitative terms. The purpose of this section is to summarize some of the more important facts and issues regarding the potential significance of resource recovery and waste reduction to these areas of national concern.

Community Solid Waste Management

Solid waste management problems at the local level can be grouped into three interrelated categories: (1) increasing costs of collection and disposal; (2) increasing political and social difficulties in locating new land disposal sites; and (3) increasing requirements for controlling pollution from local incinerators and landfill sites. These problems are shared by virtually all of our cities to some degree. They will continue to become more severe over time so long as waste generation continues at its present high and rising level.

Collection and Disposal Costs. It currently costs $21 to collect a ton of solid waste and $5 per ton to process and landfill it. These are national average figures for 1974 reflecting current practices in which a majority of communities do not provide environmentally adequate disposal facilities.* From a national perspective, these average local cost figures imply a total direct cost of about $3.5 billion to collect and dispose of the nation's 135 million tons of post-consumer solid waste in 1973.

It is expected that a majority of communities will experience increasing costs over the next 5 to 10 years. These will be increases in "real" costs–i.e., increases over and above those expected due to general effects of inflation on wage rates and prices of equipment and materials. These increases will have two main causes: pollution controls and increased scarcity of available landfill sites.

Increased requirements for pollution control, imposed by State and regional environmental protection agencies in conjunction with Federal guidelines, will impact directly on both incinerator costs and sanitary landfill costs. Increasing scarcity of available landfill sites, brought on by suburban growth, will also mean increased costs, not only for land itself but also for transporting waste over longer haul distances to outlying sites and for additional processing, such as shredding or baling, that may be required to extend the capacity of landfills.

It is not possible to predict accurately what the combined impacts of these various factors will be on average national costs over the next decade or so. However, it is not unreasonable to expect that the average community will face a 20- to 30-percent increase in its direct real costs of solid waste disposal by 1985, even without adding on the effects of general inflation. This implies a national average cost by 1985 of $8 to $12 per ton for disposal (including transfer stations and processing) and perhaps $30 to $35 per ton for collection and disposal combined. The effects of general inflation on wage rates and other cost factors would, of course, push these estimates to higher levels. Adding on an average 4 percent per year inflation rate, for example, would imply a 1985 collection and disposal cost for the average city of $50 per ton.

Landfill Siting. As many community leaders will attest, obtaining new land disposal sites involves social and political problems that go far beyond the question of land cost alone. Increasingly, local zoning ordinances and neighborhood political pressure groups are becoming effective instruments for preventing any new landfill site development within certain political jurisdictions. The opposition stems mainly from concern about the effects on the status, esthetic qualities, traffic patterns, etc., of the areas surrounding proposed sites, and the consequent effect on property values. In a very real sense, the extent of local opposition to new landfill sites is a proxy measure of the implicit costs that people who live in the vicinity of such sites typically experience. In short, it is a reflection of expected "external costs" of future land disposal–costs that are never reflected in community budget figures, but which are nonetheless real. A community's inability to establish new landfill sites can result in continued operation of obsolete or inadequate incinerators or overburdening of current landfill facilities. It can also lead to inordinately high dumping fees at private landfills. Such problems are becoming a primary motivating force at the local level for resource recovery and waste reduction programs that can reduce the amount of waste going to landfills.

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*Depending on local circumstances and level of services provided, reported collection costs vary between $10 and $30 per ton among different localities. Actual disposal costs may range from under $1 per ton for uncontrolled land dumping up to as high as $15 to $20 per ton for incineration (with air pollution controls) and landfilling of the residue. These are direct costs only and do not include any imputed economic value for the "external" environmentally related social costs of waste disposal.

Pollution Control Requirements. Environmental protection objectives require the control of solid waste incineration and landfill operations for public health, ecological, and esthetic reasons.

As of mid-1972, nearly 200 municipal-scale incinerators operated in the United States, processing waste at a rate of about 17 million tons per year.[5] Incinerators produce a variety of atmospheric emissions, and many are also a significant source of untreated wastewater effluent. Historically, incinerators have had a very poor air pollutant control record. Most are in the Northeast quarter of the nation, with over one-half being in the densely populated eastern seaboard States. Thus, their principal contributions to pollution are in areas where the damages are likely to be the greatest.

Most of the solid waste tonnage goes directly to open dumps and landfills. Although open dumps have long been considered unacceptable from both esthetic and public health standpoints, the greater part of municipal waste is probably still disposed of in this manner. As recently as the summer of 1972, it was determined that more than 14,000 disposal sites classified as dumps still operated in the United States. And although sanitary landfills have usually been considered environmentally acceptable, very few have been designed to control leachate. There is increasing evidence that potential underground leachate problems are more serious than previously thought, with adverse implications for the quality of both ground and surface waters.[6]

There are real questions regarding how rapidly local agencies can progress toward environmentally acceptable incinerators and landfills in the face of rising waste loads and rising costs of implementing the desired controls. To the extent that such progress is made, it will be reflected in steeply higher costs of waste disposal. To the extent that control implementation lags, environmental quality will deteriorate further due to the increasing per capita solid waste generation rates.

Conservation of Natural Resources

By a variety of measures, we are becoming an increasingly "material-intensive", society. Not only have we increased our per capita consumption of goods and services, in many cases we have also increased our rate of material use per unit of product consumed. This is reflected both in the waste flow estimates and in basic production and consumption statistics. For example, U.S. consumption of most classes of raw materials has been growing by 20 to 40 percent per decade in the 20th century, and there is some evidence of an increasing rate of growth during the most recent decades.[1, p. 10] EPA's projections indicate 10- to 60-percent increases in consumption of various raw materials and fuels by 1985 over 1972 levels. Typical projections by independent resource economists forecast at least a doubling in U.S. consumption of most raw materials by the year 2000.[7, 8]

Along with increasing material consumption has come an apparently increasing dependency on foreign mineral resources during the post-World War II era.[9] This undoubtedly has been largely a function of the economics of supply rather than our own "running out of resources" in any absolute sense. An important factor here was the overvaluation of the dollar in international trade during most of the past three decades. However, it also reflects the fact that for some raw materials (such as tin and nickel) the

United States does not possess known commercial-scale deposits, and that for some others (such as iron ore) most of our higher grade and more accessible deposits have already been largely depleted.

In the context of international trade, a new system of floating exchange rates together with new instances of nationalization and cartelization of the world's natural resources has to a significant degree created new ground rules regarding access to foreign raw material and energy sources. At the same time, the structure of competition for foreign resources has drastically changed with the rapid economic growth of the U.S.S.R., Japan, and a number of other nations.

The general conclusion is that the world's natural resource base, including that of the United States, will be subject to increasingly extreme pressures over time, and that the international system of distributing these resources will be less favorable to U.S. consumption than in the past. This implies an altered future price structure, with the United States facing generally higher world market prices for many if not most of its imported raw materials and fuels. Under such circumstances, the natural response will be to turn increasingly inward to domestic sources, where possible, in order to reduce adverse effects on specific product prices and foreign trade balances, and to preserve national political autonomy. Our policy of domestic energy development—Project Independence—is a case in point.

From a domestic economic standpoint, the key issues relate to possibilities of future shortages of important industrial raw materials and fuels with attendant decreases in material welfare. These shortages could occur from a technological inability of the United States and other countries to develop new low-cost raw material supplies in pace with rising world demands. They could also result from trade restrictions associated with international power struggles, or simply from attempts of key supplying nations to maximize their returns from trade.

The extent and timing of future shortages is subject to much conjecture and debate.[10-12] Because there is no adequate way at present to assess the relative quantitative importance of these perceived problems, there is no satisfactory basis for quantifying the present social value of resource conservation in monetary or other terms. Nevertheless, few would deny that conservation values are important even though we may not be able at this time to quantify them.

Last year's *Report to Congress* indicated the approximate contributions that a maximum feasible nationwide resource recovery effort might make toward meeting current demands for materials.[2, p.14] Those EPA estimates suggested that 6 to 11 percent of current annual U.S. production of various major metals and up to 20 percent of current paper production could technically be supplied by recycling materials from the post-consumer solid waste stream (as defined in Table 1). Additional resource conservation and foreign trade benefits would stem from waste reduction measures.

More recent work has focused on quantifying the potential national energy savings associated with material recycling, conversion of organic waste into fuels, and waste reduction approaches.[13] The calculations indicate that energy savings well in excess of 1,000 billion Btu (between 1.5 and 2.0 percent of total U.S. energy requirements) could have been achieved in 1972 through waste reduction and resource recovery measures using currently available technology. This suggests the relative order of magnitude of future national potentials for energy conservation through improved solid waste management.

Although such magnitudes could not be considered, by themselves, to be ultimate solutions to our resource supply problems, they would nevertheless represent substantial contributions in both raw material and energy terms.

Environmental Protection

The preservation and improvement of environmental quality represents a third set of problems for which resource recovery and waste reduction can contribute some measure of solution. Degradation of the environment involves physical, chemical, and biological damages from such causes as: the physical destruction of land surfaces by mining and construction, soil erosion from improper forestry and agricultural practices, the contamination of air and water by industrial effluents, the eutrophication of lakes and ponds, toxic chemicals introduced into biological food chains, and accumulations of industrial and municipal solid wastes as litter or at dump sites. Environmental degradation adversely affects virtually all of the measures of human welfare–health, economic, and esthetic.

Resource recovery and waste reduction most obviously can affect the direct environmental impacts of waste collection and disposal, as discussed earlier. However, the environmental implications of these nondisposal approaches extend far beyond the local incinerator and dump site, since they are inextricably linked to the industrial structure of the economy. Thus, for example, whenever a waste reduction measure reduces the quantity of a material consumed, the quantities of all direct and indirect raw material and energy inputs–and their associated environmental impacts–are correspondingly reduced to some extent. These direct and indirect industrial impacts include not only the raw materials physically included in the final product (such as the iron, aluminum, tin, and lead in a tinplated can) but also the ancillary process chemicals and the fuels required for heat, power, electricity, and transportation. The reduced demands extend back through the material refining stages to crude material preparation and extraction from the earth. They could in some instances also extend indirectly through the industrial structure to capital equipment requirements and the industries that supply them.

Resource recovery has similar implications, except that some offsetting adverse environmental effects can be expected, both in mixed-waste recovery and subsequent industrial processing of the recovered material (such as secondary smelting). Thus far, research results indicate that the environmental effects of recycling are almost always significantly less–usually only a small fraction–compared with those resulting from virgin production.[14-18] With rare exceptions, this holds for all air and water pollutants (both process and energy-related) as well as solid waste generation and degradation of land surfaces.

At this time it is not possible to predict how environmental benefits of particular actions, in the form of reduced environmental impacts from industry, will be distributed across geographic areas and industry groups. Small increments of waste reduction or recovery may have no observable impact at all, since many effects of industrial processes may be insensitive to small changes in material throughput. One of the real difficulties in evaluating the total environmental significance of waste reduction and resource recovery efforts is the diffusion of individual effects across many different industries and geographic regions. As with material and energy conservation benefits, these environmental benefits are not likely to appear either obvious or of much real significance to those at the local decision-making level. In fact, the national industrial pollution control benefits from any one State or local resource recovery or waste reduction project are likely to be so small as to be virtually undetectable. Nevertheless, the total benefits from a multitude of individual local actions can add up to results of national significance.

REFERENCES

1. Franklin, W. E., et al. [Midwest Research Institute]. Base line forecasts of resource recovery, 1972 to 1990. Washington, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Resource Recovery Division, Mar. 1975. 376 p. (Unpublished report.)
2. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; second report to Congress. Environmental Protection Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p.
3. Smith, F. L., Jr. A solid waste estimation procedure; material flows approach. Environmental Protection Publication SW-147. [Washington], U.S. Environmental Protection Agency, May 1975. 56 p.
4. Smith, F. A. Comparative estimates of post-consumer solid waste. Environmental Protection Publication SW-148. [Washington], U.S. Environmental Protection Agency, May 1975. 18 p.
5. Achinger, W. C., and R. L. Baker. Environmental assessment of municipal-scale incinerators. Environmental Protection Publication SW-111. [Cincinnati], U.S. Environmental Protection Agency, 1973. 31 p. [Open-file report, restricted distribution.]
6. Garland, G. A., and D. C. Mosher. Leachate effects of improper land disposal. *Waste Age*, 6(3): 42, 44-48, Mar. 1975.
7. Ridker, R. G. The economy, resource requirements, and pollution levels. *In* U.S. Commission on Population Growth and the American Future. Population, resources, and the environment. Washington, U.S. Government Printing Office, 1972. p. 35-37. (Commission Research Reports Vol. 3.)
8. National Commission on Materials Policy. Towards a national materials policy; basic data and issues–an interim report. Washington, U.S.

Government Printing Office, Apr. 1972. 63 p.

9. U.S. Department of the Interior. Mining and minerals policy, 1973; second annual report of the Secretary of the Interior under the Mining and Minerals Policy Act of 1970 (P.L. 91-631). Washington, U.S. Government Printing Office, June 1973. 73 p.

10. Meadows, D. H., et al. The limits to growth. New York, Potomac Associates, 1972. 207 p.

11. Fischman, L. L., and H. H. Landsberg. Adequacy of nonfuel minerals and forest resources. *In* U.S. Commission on Population Growth and the American Future. Population, resources, and the environment. Washington, U.S. Government Printing Office, 1972. p. 77-101. (Commission Research Reports Vol. 3.)

12. Goeller, H. E. An optimistic outlook for mineral resources. Presented at University of Minnesota Forum on Scarcity and Growth; Towards a National Materials Policy, [Minneapolis], June 22-24, 1972. Oak Ridge, Oak Ridge National Laboratory-National Science Foundation Environmental Program. 23 p., app.

13. Lowe, R. A., M. Loube, and F. A. Smith. Energy conservation through improved solid waste management. Environmental Protection Publication SW-125. [Washington], U.S. Environmental Protection Agency, 1974. 39 p., app.

14. Yaksich, S. M., et al. [Calspan Corporation]. Environmental impacts of virgin and recycled steel and aluminum. Washington, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Feb. 1974. 116 p. (Unpublished report.)

15. Gordian Associates, Inc. Environmental impacts of production of virgin and secondary paper, glass and rubber products. Washington, U.S. Environmental Protection Agency, 1975. (In preparation.)

16. Hunt, R. G., and W. E. Franklin. Environmental effects of recycling paper. MRI 1106. Presented at 73d National Meeting of the American Institute of Chemical Engineers, Minneapolis, Aug. 27-30, 1972. Kansas City, Midwest Research Institute, [July 1973]. 34 p.

17. Haller, G. L. [Monsanto Company]. Resource utilization and environmental impact of alternative beverage containers. Presented at Symposium: Environmental Impact of Nitrile Barrier Containers, Hartford, Conn., July 19, 1973. 2 v.

18. Hunt, R. G., et al. [Midwest Research Institute]. Resource and environmental profile analysis of nine beverage container alternatives; final report. v. 1-2. Environmental Protection Publication SW-91c. Washington, U.S. Environmental Protection Agency, 1974. 178 p.

Chapter 2

WASTE REDUCTION

Waste reduction (or "source reduction") includes a variety of means to control and prevent waste generation through product redesign and change in consumer behavior. It is a unique approach to solid waste management based on the thesis that solid wastes are the unwanted residuals of our production and consumption processes–as are airborne and waterborne wastes–and that the generation of such residuals should be reduced. As presently understood, some of the major choices in production and consumption that are relevant to solid waste generation are:

1. Single-use versus multiple-use design
2. Shorter versus longer product lifetime (durability)
3. Larger versus smaller products
4. More versus less packaging material per unit of product
5. More versus fewer units of product consumed per family per year

In the past decade, there has been considerable progress in the development of systems for the storage, collection, transportation, processing, and disposal of solid waste. More recently, several systems for the recovery and utilization of material from solid waste have also been developed. However, little attention has been focused (by either the private or public sectors) on a third approach to solid waste management–reducing the generation of waste.

Nor has much consideration been given to moderating the demand for materials and products in order to reduce energy and materials consumption. While the Federal Government has long sought to increase the available supply of raw materials, its efforts have been directed generally toward the short-run exploitation of natural resource assets. The Mining Law of 1872, depletion allowances, and Federal subsidies for resource exploration and technology are some of the principal ways in which public policy has encouraged the increase of raw materials supply. Such efforts to increase supply, however, also have the effect of encouraging consumption of materials and spurring the growth in consumption which can in some ways be related to current energy and materials shortages.

While in past years proponents of waste reduction have been limited generally to the "gloom and doom" prophets of the environmental community, recently the concept has been accorded wider credence. Energy and material shortages have created market pressures for decreased consumption of raw materials. Industry has responded by developing new product designs that utilize resources more efficiently. At the same time, new public policies have been announced that urge decreased consumption of fossil fuels. The nation's cities have also become more and more concerned about solid waste management practices and generation rates, particularly as the use of landfills becomes more costly and politically difficult. A recent survey of cities indicated that waste reduction was perceived to be one of the major solid waste management issues that needs to be addressed. The questions that now arise, therefore, go beyond the issue of whether waste reduction is desirable. They now center on the extent to which feasible approaches for decreasing material consumption and waste generation can be developed and implemented.

As an approach to material shortages, waste reduction is unique in that it results in the preservation of the quality of the physical environment whereas many other approaches involve the relaxation of environmental standards. Similarly, while most approaches to waste management have dealt with the means of disposing of wastes without considering the environmental pressures generated in the creation of wastes, waste reduction would decrease environmental effects from the time of the extraction of raw material through to the final disposal stage.

The *Second Report to Congress* described the waste reduction concept in general terms and provided specific information on the growth of packaging waste. This chapter is intended to describe in more detail the technical options that can be utilized to achieve waste reduction and the types of actions that can be undertaken by the Federal Government to encourage a reduction in the use of energy and materials and in waste generation.

TECHNICAL OPTIONS

Three technical options have been identified as means of achieving waste reduction:

1. *Reduced resource use per product*–the designing of products so that minimum quantities of resources are used in their manufacture (e.g., a thinner-walled container).
2. *Increased product lifetime*–the use of products over an extended period of time (e.g., use of a tire with a longer service life), and the designing of products for longer life.
3. *Product reuse*–the multiple use of products in their original forms (e.g., the use, washing, and refilling of a glass bottle) and the designing of products for multiple uses.

The following describes each of these options and presents data on the potential impact of each option on particular products selected as examples.

Reduced Resource Use Per Product

The Concept. This approach will result in a decrease in the amount of materials used in the manufacture of a product. It is likely to decrease energy consumption (due to reductions in the energy required both to produce the raw material and to fabricate the product) and solid waste generation. Reduced resource use is also a major means of cutting industry costs and, as such, is often accomplished by the working of normal market forces.

A number of factors have, however, served to slow improvements of this type. These include a general resistance to change, producer investment in current practices and technologies, and inadequate data and information to assess the impacts of particular design changes. Also, manufacturers generally do not take potential reductions in pollution and solid waste into account when designing a product, and these benefits have not heretofore served as effective inducements to change.

Nevertheless, it must be noted that cost reductions can accrue to both the producer and consumer from this option. A reduction in resource use per product, particularly during a time of rapidly increasing raw material prices, can be of substantial aid in reducing overall production costs. If these savings are then passed on to the consumer by means of lower prices, they will also result in significant anti-inflationary benefits. To the extent that materials are imported, reducing resources consumed can also affect favorably our balance-of-payments burden. It is possible, however, that in some cases decreased natural resource use will be offset by increases in labor costs and that no actual dollar savings will occur.

Applicability and Extent of Impact. Insufficient data exist at the present time to assess accurately all the products that could be redesigned to conserve resources. Theoretically, however, every manufactured product could be considered from the perspective of minimizing material use.

In steel can design, for example, it has been estimated that by replacing the currently used soldered three-piece steel can with a two-piece drawn and ironed can, a steel savings of 25 to 30 percent will occur.[1, p. 7] If this design change, for which the technology is now becoming available, were applied to all cans used to contain food, it would result in a savings of approximately 1 million tons of steel and tinplate per year at 1973 production levels.*

Other design changes have also been identified. A lightweight but strong glass bottle has been designed that would use 20 to 25 percent less raw material.[2] Design changes in paper packaging are also possible. One sporting equipment company has recently reported a savings of 30 percent on packaging requirements;[3, p. 43] a glass bottle shipper has esti-

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*EPA estimate based on: Kalina, J. F. Now it's seamless steel cans for food. *Modern Packaging*, 47(10):7-8, 16, Sept. 1974.

mated a savings of 48 percent on corrugated by removing interior separators and changing the sizes of the shipping carton.[4] Additional paper savings could be obtained by using thinner gauge paper in newspapers and tape; this is now being done on a small scale.

One major design change that would significantly reduce resource usage would be the redesign of the automobile to make it smaller and lighter. In 1973 over 9.5 million domestically produced automobiles were sold in the United States.[5] If each car were only 300 pounds (8 percent) lighter on the average, a savings of about 1.5 million tons of material would occur. And recent drops in sales of big cars (over 3,500 pounds) show how swiftly buyers will switch to smaller automobiles when fuel is scarce and costly.[6]

Numerous other examples could be cited of possible design changes and resultant savings in materials. Two design options for which data on resource utilization and environmental effects have been developed in detail are a new half-pint milk container and the packaging of products in larger rather than smaller amounts.

The Half-Pint Milk Container. Milk is now purchased by consumers in four major container sizes: gallons, half gallons, quarts, and half pints. In 1973, an estimated 7,056 million gallons of milk were consumed in the United States.[7] Of that amount, approximately 11 percent was packaged in half-pint containers (Table 6). The modern paperboard milk container, used for all container sizes, came into the market in 1935. While improvements have been made, such as the replacement of wax coatings with plastic coatings, the standard half-pint container has not been changed significantly in shape since its introduction.

Recently, however, a new design has been introduced and is being marketed in several parts of the country. This design change reduces the size of the base of the container from a square of 2¾ inches to one of 2¼ inches.[8] By thus changing the shape of the container, the material consumed in packaging each half pint of milk is reduced substantially. The new container with the smaller base has been estimated to use 31 percent less paper and 16 percent less low-density polyethylene than the old container. If all half-pint containers now produced were made using this new design, an estimated annual savings of 59,000 tons of paper and 4,000 tons of polyethylene would result (Table 7). These reductions in materials can be translated directly into reductions in solid waste—a total decrease of some 63,000 tons annually.

TABLE 6

USE OF DIFFERENT-SIZED CONTAINERS FOR MILK, BY PERCENT OF VOLUME OF MILK SOLD, 1973*

Size	Percent of milk volume
Gallon	35
Half gallon	39
Quart	8
Pint	2
Half pint	11
Bulk and other	5
	100
Total gallons consumed	7,056 million

*Milk Industry Foundation. Unpublished data.

In addition, reductions in energy use and pollution would result from the need to process less raw material into final products. The extent of the pollution reduction depends, of course, on the level of operating pollution controls. Based on anticipated 1976 control standards for air and waterborne pollutants, air emissions would be reduced by about 1,600 tons and waterborne wastes would be reduced by over 600 tons as a result of the paper savings alone (Table 8). Energy saved by not producing the paper would amount to over 2.3 trillion Btu annually.* This is equivalent to 1,100 barrels of oil per day.

While these values are small compared to national pollution problems and resource needs, it is important to point out also that the design change will likely result in dollar savings to both producer and consumer. Based on current paperboard and polyethylene prices, it has been estimated that a savings of some 10 million dollars would accrue to the purchasers and fillers of the milk cartons,[8] and this could be reflected in lower prices for the consumer.

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*EPA estimate based on unpublished data provided by International Paper Company.

TABLE 7
MATERIALS USED IN STANDARD AND NEW HALF-PINT MILK CONTAINERS*

	Pounds per 1,000 gallons			Total consumed (1,000 tons)
	Paper	Polyethylene	Total	
Standard half pint	488	62	549	213
New half pint	336	52	388	150
Material conserved	152 (31%)	10(16%)	161 (29%)	(63)

*International Paper Company. Unpublished data.

Package Size. For virtually all products studied, the use of a larger package size meant that less packaging material was required per unit of weight or volume of the product. The 7-ounce returnable glass bottle requires about twice as much glass per ounce of soft drink as the 32-ounce size.[9] Similarly, the 3-ounce toothpaste tube (including the cap) requires 50 percent more material per ounce of toothpaste than the 7-ounce size.[10] Also, the "8Z tall" can (approximately 8-ounce capacity) for processed vegetables, which contains about one-half the volume of the "No. 303" can, requires 25 percent more steel per ounce of product.*

How the weight-to-volume ratio drops as container size increases has been examined in detail for the cylindrical high-density polyethylene containers in which liquid bleach and other household products are sold (Table 9). The consumer may buy 128 ounces of bleach by purchasing one 128-ounce container or ten 12-ounce containers and one 8-ounce container. In the former case, 120 grams of polyethylene are required; in the latter case, 303 grams are required, or 153 percent more plastic packaging material.[11]

Of course, the savings in materials also represents a reduction in air and water pollution and solid waste associated with the manufacture, distribution, and disposal of these materials. The extent of reduction of these environmental impacts is not strictly proportional to the container material savings. Energy requirements for some processes, such as container filling and transportation, are dependent on other

TABLE 8
ESTIMATES OF REDUCTIONS IN ENVIRONMENTAL IMPACTS THAT WOULD OCCUR DUE TO REDUCED PAPER CONSUMPTION IF ALL HALF-PINT MILK CONTAINERS WERE OF THE NEW DESIGN*

	Reduction per 1,000 tons of folding boxboard conserved	Total reduction (59,000 tons of paper conserved)
Air emissions (tons)	26.67	1,574
Water pollutants (tons)	10.50	620
Industrial solid waste (tons)	90.45	5,337
Energy usage (million Btu)	39,336	2,320,824

*EPA estimate based on: Gordian Associates, Inc. *Environmental Impacts of Production of Virgin and Secondary Paper, Glass and Rubber Products.* Washington, U.S. Environmental Protection Agency, 1975. (In preparation.)

TABLE 9
EFFECT OF SIZE INCREASES ON THE WEIGHT/VOLUME RATIO OF A HIGH-DENSITY POLYETHYLENE CONTAINER*

Volume of product contained (oz)	Average weight of container (grams)	Weight/volume ratio
4	12	3.00
8	23	2.88
12	28	2.33
16	34	2.12
32	52	1.62
128†	120	0.94

*Owens-Illinois Corporation. Unpublished data.
†This container includes a handle.

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*EPA estimate based on data from: *The Almanac of the Canning, Freezing, Preserving Industries.* Westminster, Md., Edward E. Judge & Sons, Inc., 1973. 586 p.

factors, such as the number of containers or the stacking volume of the containers. However, the major environmental impacts of container manufacture occur during the acquisition and processing of the raw materials. For these activities, the reductions in environmental impacts are virtually proportional to material savings.

The savings in materials that result when 32-ounce returnable glass soft-drink bottles are used instead of the 7-ounce size amounts to 51.6 percent of packaging material per ounce of beverage. The reductions in other inputs and outputs have also been calculated (Table 10).

TABLE 10

REDUCTION IN ENVIRONMENTAL IMPACTS RESULTING FROM USE OF 32-OUNCE INSTEAD OF 7-OUNCE SOFT DRINK BOTTLES*

Category	Reduction per ounce of beverage contained (%)
Thermal energy requirement (Btu)	51.0
Electrical energy	50.5
Transport energy	40.3
Process water pollutants (lb)	51.6
Process air emissions	51.5
Power generation air emissions	50.5
Transport air emissions	38.7
Process solid wastes	51.5
Paper packaging (e.g., corrugated)	(No significant reduction in this case)

*EPA estimate based on data supplied by Glass Container Manufacturers Institute.

Mainly because of the material costs saved by switching to larger sizes, a trend toward larger sizes has developed during the past few years for many products, such as bottled soft drinks. A leading market research organization has found a significant shift to larger sizes for a representative sample of household, food, and toiletry items. The trend is evident in the industrial sector as well, where, for example, the 66 2/3-pound shipping bag is beginning to replace the conventional 50-pound bag. The advantage of reducing packaging is exemplified in the wholesale costs of electrolytic metal cans for processed vegetables. For packaging the same total volume, "No. 3 cyl." cans (80.5 cubic inches) are half as expensive as "8Z tall" cans (13.48 cubic inches). The cost of the package is a significant share of the total cost for numerous products, so the package savings in larger sizes often is reflected in a lower per-ounce purchase price for the product. The trend to larger sizes has also been spurred by the convenience to consumers of making fewer trips to market and by new product designs such as resealable closures and lighter weight containers.

There are, however, many limitations to converting to larger sizes. Some products have limited shelf life. Others may spoil quickly once the package seal is broken. Many consumers have limited storage space, particularly for foods which must be refrigerated. The consumer may also value the convenience of handling a smaller container.

Design for Longer Life

The Concept. Product lifetime is the length of time household consumer goods remain in use from purchase to final discard. The useful lifetime of products clearly impacts upon the waste stream. As product life increases, solid waste generation per unit of time for the product decreases. And, along with its recyclability and its recoverability from the waste stream, the useful lifetime of a product will influence where and when that product will end up as waste.

It should be noted that product lifetime is a relatively complex attribute of goods. It depends not only on the durability aspects of the original design, but also on such sociological and economic factors as obsolescence, styles and fashions, cost of replacement, ease of repair, household space limitations, and possibly also cost of disposal.

Applicability and Extent of Impact. The concept of extended useful life can be applied to relatively short-lived products, such as paper towels and throwaway paper and plastic tableware. For present purposes, however, discussion will be limited to extending the lifetime of certain durable goods.

All household durable goods currently comprise no more than 10 to 15 percent of collected solid wastes. National Industrial Pollution Control Council data indicate that major household appliances contributed about 2.2 million tons in 1971 to the nation's solid waste stream.[12 p. 22] This is less than 2 percent of municipal waste by tonnage or compacted volume. Tire wastes represent an additional 2.6

million tons. Automobiles represent a focus of heavy resource utilization, although most auto hulks are eventually recycled and do not enter the municipal waste stream. Some possible impacts of the extended lifetime option are indicated by the following information on tires and automobiles.

Passenger Car Tires. The rubber industry records that, in 1970, it enjoyed sales of $11 billion annually, employed 500,000 people, and consisted of more than 2,000 manufacturing plants operated by 1,500 companies.[12, p. 15] Tires represent 70 percent of total rubber industry sales volume. In 1973, 192.6 million passenger car tires were produced in the U.S.[13] In the same year, 35 million used tires were retreaded, 17.5 million went to reclaiming plants, and 3.7 million were used up in tire splitting, reef building, or other applications.[14] An estimated 144 million waste tires therefore either accumulated or found their way into dumps or landfills. This figure, compared with an estimate of 112 million tires discarded 10 years earlier, reflects a growth in tire wastes of 3 percent annually.[15, p.14]

There are three general categories of passenger tire: bias, belted bias, and radial ply. The bias tire is the most inexpensive initially and should provide satisfactory performance for 15,000 to 20,000 miles. Longer mileage (approximately 30,000) and greater blowout protection can be provided by the more expensive belted bias tire. The top of the tire line both in price and performance is the belted radial ply tire, which should deliver satisfactory performance for greater than 40,000 miles.

The passenger tire market can be broken down into two segments: original equipment (30 percent) and replacement tires (70 percent). A significant trend in tire sales is the shift in replacement sales away from bias ply tires toward longer lasting belted bias tires (Table 11). Even more dramatic is the trend in original equipment sales toward long-lasting radial ply tires.

The trend toward longer life tires represents a new opportunity in tire waste management. It has been estimated, for example, that a shift in original equipment tire purchases exclusively to radial ply tires would result in a decrease of 38 percent in tire wastes currently generated each year.[15, p. 144]

TABLE 11
TIRE SALES BY CONSTRUCTION TYPE, 1972-75*

Construction type	Percent of sales			
	1972	1973	1974†	1975†
Replacements (70%):				
Bias	54	45	42	38
Belted bias	38	42	39	38
Radial	8	13	19	24
	100	100	100	100
Original equipment (30%):				
Bias	16	18	13	9
Belted bias	78	64	46	30
Radial	6	18	41	61
	100	100	100	100

*Domestic tire market profile. *Modern Tire Dealer*, 55(6):54-70, Jan. 1974.

†Data for 1974 and 1975 are projections.

Table 12 presents the results of an analysis of the resource conservation and waste reduction effects of a hypothetical 100,000-mile tire. Such a tire is not currently available, but some experts feel that its development is not unfeasible in the foreseeable future. Table 12 depicts a scenario where all original equipment tires purchased after 1978 would last for 100,000 miles, and all replacement tires are retreaded

TABLE 12
THE EFFECT OF A HYPOTHETICAL NEW 100,000-MILE TIRE UPON TIRE WASTES AND REPLACEMENT TIRE SALES*
(In millions of tires)

Year	Tire wastes		Reduction in sales/wastes
	Baseline, without new tire	Projected, with new tire	
1974	192	192	–
1978†	207	207	–
1980	201	203	2
1985	234	129	105
1990	246	103	143

*EPA estimates based on: Westerman, R. G. *The Management of Waste Passenger Car Tires.* Dissertation, University of Pennsylvania, Philadelphia, 1974. 239 p.

†Program initiated in 1978 consisting of all 100,000-mile tires as original equipment and 27,000-mile retreaded tires as replacement tires.

100,000-mile tires that would last for an additional 27,000 miles. Under these circumstances annual tire waste and consumption would be reduced by 143 million tires by 1990.[15, p. 144]

Such a reduction in tire consumption would represent a savings to the country of 23 million barrels of oil, 1.75 million tons of rubber, and 525 million pounds of carbon black.* There would also be further positive environmental impacts associated with decreases in the production of these materials. Solid waste savings also would be significant. Assuming a disposal cost of 25 cents per tire (including shredding), decreased solid waste generation will result in savings approaching $35 million in 1990.* Cost advantages for the consumer and disadvantages suffered by industry are less clear and would depend to some extent upon projected prices of the original tire. The long-term economic effects resulting from decreased replacement tire sales should be the subject of further study. Furthermore, as noted, the technical feasibility of 100,000-mile tires has not been demonstrated, and the safety characteristics of such tires have not been evaluated.

Automobiles. The auto industry consumed 20 percent of the steel, 9 percent of the aluminum, 8 percent of the copper, 50 percent of the malleable iron, 65 percent of the rubber, and 33 percent of the zinc consumed in this country in 1972.[5, p. 53] In all, the industry used over 22 million tons of metals and rubber in 1972. The motor vehicle and allied industries account for one-sixth of the country's gross national product and employ about 13 million workers.[5, p. 52] These figures are of particular significance when one considers projected growth rates in the auto industry. In 1950, an estimated 7.5 million automobiles were purchased.[16] By 1970, this figure had risen to 8.2 million. Projections indicate that by 1990, approximately 14.3 million cars will be purchased each year in the United States.[16]

The useful life of a car in the United States is currently very similar to what it was 20 years ago—approximately 10 years.[16] (In other countries, however, the lifetime of U.S. automobiles is often more than doubled.) Current automobile weights have, however, risen significantly. Thus, between 1960 and 1972, the average weight of a composite middle-sized automobile rose 9.7 percent, from 3,574 pounds to 3,923 pounds.[17, p. 10] This has meant increased resource use per car despite the fact that lifetimes have remained virtually constant.

Automobiles with longer lifetimes could, however, significantly impact upon the amount of resources used in automobile manufacture. If we assume that current weights (and material compositions) remain constant, we can project material savings for a car with a 12-year life.

If all cars sold in 1980 were designed for a 12-year lifetime, then by 1990 (assuming a steady-state situation has been reached) new car sales would decrease by approximately 20 percent to 11.5 million units.† The resource and solid waste savings throughout the phases of the automobile life cycle would be an estimated 6.7 million tons annually. By specific material, this would translate into 5.5 million tons of steel, 151,000 tons of aluminum, and 142,000 tons of zinc.[5]

While it appears that longer life automobiles would result in resource savings and reduced waste generation rates, the economic and technical performance factors of increased automobile durability and lifetime have not been evaluated to date.

Reuse

The Concept. The principle of reuse should be considered in relation to the broad and increasing category of products that are now designed for one-time use. Reuse is different from recycling in that the products are not reprocessed and refabricated but are used in their original form. Product reuse has significant impacts upon litter, material and energy consumption, and solid waste generation.

Applicability and Extent of Impact. The design and manufacture of products that are reusable is only one determinant of the feasibility of reuse. Obviously, the behavior of the users will determine the number of times a particular item will be reused. There are two general cases where product reuse could occur. In the first case, the use and reuse of the product is internal to the organization (e.g.,

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*EPA estimate based on Westerman, *Waste Passenger Car Tires*, 1974.

†Calculation based on data from: U.S. Department of Transportation, *Motor Vehicle Distribution, Production, and Scrappage*, Jan. 1973.

reusable corrugated shipping containers employed by moving companies, cloth napkins used by a homeowner, etc.). In the second case, the use and reuse of the product requires handling by different individuals (e.g., the refillable bottle is reused by a bottler but used once by an individual consumer). In both cases, some system must be implemented to retrieve the product undamaged and ready for reuse. The incentives required to achieve the desired behavior would differ substantially, however.

Beverage Containers. In 1972, almost 56 billion beer and soft drink containers were produced and used in the United States.[18] This resulted in the generation of approximately 8.2 million tons of solid waste, or approximately 10 percent of the nonfood product waste stream, and the use of an estimated 388 trillion Btu of energy.* A shift to a refillable bottle system would remove 5 to 6 million tons of material from the waste stream, and decrease beverage container litter by 60 to 95 percent.† In addition, the shift to an all-refillable system would reduce air emissions and waterborne wastes, and would save an estimated 218 trillion Btu of energy per year (Table 13). This energy savings is equivalent to over 108,000 barrels of oil per day. (For the effects of a system in which 90 percent of the containers are refillable, see Table 21.)

Reusable and Paper Plates. Another example studied was reusable versus disposable paper plates. Paper plates are made from SBS (solid bleached sulfate) board, a high-grade paper product. It is assumed that 15 percent of the board by weight is lost as trim in making a plate. The estimated weight of 1,000 nine-inch standard plates ranges from 21 to 24 pounds.[19] Each plate will require .025 to .028 pound of solid bleached sulfate board, including the 15-percent loss.[19]

Data on the environmental and energy impacts of

TABLE 13

ENVIRONMENTAL IMPACTS FROM CURRENT MIX OF BEVERAGE CONTAINERS AND FROM ALL-REFILLABLE SYSTEM, BASED ON 1972 DATA*

	Current system					All refillables	Reductions	
	10-trip refillable	One-way glass	Bimetal can	Aluminum can	Total		Amount	Percent
Raw materials (million lb)	3,578	15,375	7,482	1,619	28,054	12,280	15,774	56
Energy (trillion Btu)	50	131	146	61	388	170	218	56
Water use (billion gal)	35	75	93	12	215	121	94	44
Industrial solid waste (million cu ft)	20	68	253	29	370	70	300	81
Atmosphere emissions (million lb)	216	532	605	263	1,616	741	875	54
Waterborne waste (million lb)	80	115	94	48	337	274	63	19
Post-consumer waste (million cu ft)	27	84	9	2	122	94	28	23

*Hunt, R. G., et al. [Midwest Research Institute]. Resource and environmental profile analysis of nine beverage container alternatives; final report. v.1-2. Environmental Protection Publication SW-91c. Washington, U.S. Environmental Protection Agency, 1974. 178 p.

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*EPA estimate based on: Hunt, R. G., et al. [Midwest Research Institute]. *Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives; Final Report.* v.1-2. Environmental Protection Publication SW-91c. Washington, U.S. Environmental Protection Agency, 1974. 178 p.

†EPA estimate based on: Bingham, T. H., and P. F. Mulligan [Research Triangle Institute]. *The Beverage Container Problem; Analysis and Recommendations.* U.S. Environmental Protection Agency, Sept. 1972. 190 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-213 341.)

SBS manufacture are summarized in Table 14 on a per 10,000-plate basis. To the production-associated wastes were added the land-use impacts of disposing of the plates through landfilling. To the extent that the plates are disposed of by incinerators, additional air pollution would be expected over that reported in the table.

TABLE 14
ENVIRONMENTAL IMPACTS OF PAPER PLATE MANUFACTURE AND DISCARD*

	Range per 10,000 plates†
Air pollutants (lb):	
Particulates	2.20-2.50
SO_x	3.80-4.20
Other sulfur compounds	1.20- .40
CO	.40-1.45
NO_x	1.74-1.95
Water pollutants (lb):	
BOD	1.25-1.40
Suspended solids	1.38-1.54
Solid wastes:	
Manufacturing waste (lb)	82.20-92.06
Plate disposal (lb)	240-280
Total landfill requirement (acres)	.20-.22
Energy requirements (Btu):	
Gross†	5,350,000-5,990,000
Fossil fuel†	2,470,000-2,760,000

*Gordian Associates, Inc. Environmental impacts of production of virgin and secondary paper, glass and rubber products. Washington, U.S. Environmental Protection Agency, 1975. (In preparation.) Table CFB V2-A.

†The fossil fuel requirement is lower than the gross requirement because some of the energy consumed in manufacturing is generated at the mill from process wastes.

To evaluate the environmental impact of a reusable plate, the effects of producing and discarding the required replacement fraction (one plate every 6,000 washings)* and the effects of washing the plate were evaluated. The latter are by far the dominant effects since each plate is washed after each use.

To determine the energy effects of washing, it was assumed that the dishes would be washed in a single-tank commercial washer. If the dishes were washed by hand, energy use would be expected to be lower. A single-tank commercial dishwasher will process 56 racks holding 25 dishes each per hour. Water requirements are 100 gallons per hour assuming a 10-second rinse at 180 degrees F. The energy requirements to heat this water are 168,000 Btu per hour or 168 cubic feet of natural gas.[20] In addition, the washer would require a 1-horsepower motor or 1.5 kilowatt-hours. The energy equivalent of this quantity of electricity is 11,365 Btu. Thus, the total energy requirements of washing 1,400 dishes (25 x 56) is 179,365 Btu.†

Table 15 contains estimates of environmental impacts and energy consumption associated with reusable plates; these may be compared with the estimates for paper plates in Table 14.

It should be obvious that the above analysis is based on several assumptions and is not in any way a comprehensive evaluation of disposable and reusable plates. However, it is useful to indicate the order of magnitude of some of the environmental and resource conservation impacts and their causes. Clearly other aspects of disposable and reusable products, such as cost and sanitation, also need to be considered. EPA currently has underway a more complete study of a series of disposable and reusable products to identify product shifts that may be desirable from an environmental point of view and to assess the economic and other impacts of such shifts.

MECHANISMS TO ACHIEVE WASTE REDUCTION

There are three types of public policy approaches currently being considered at the Federal level to achieve waste reduction:

1. Product charges to provide an incentive for decreased use of materials and products
2. Deposits as an incentive for the reuse of products
3. Encouragement of voluntary actions to reduce resource use and waste generation through shifts in product design

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*EPA estimate based on data provided by Single Service Institute.

†EPA estimate based on data provided by Gas Appliance Manufacturers Association.

TABLE 15
ENVIRONMENTAL IMPACTS OF REUSABLE DISHES
(10,000 dishes, used and washed once)

	Washing*	Manufacture†	Total
Air pollutants (lb):			
Particulates	.024	.001	.025
SO_x	–	.005	.005
CO	–	–	–
NO_x	.468	.015	.484
Water pollutants ‡	–	–	–
Solid wastes (lb):			
Indirect	–	.279	.279
Direct	–	1.666	1.666
Energy requirements (Btu)	1,280,000	.012	1,292,000

*Based on burning 168,000 Btu of gas to heat water per 1,400 plates, or 120 Btu per plate. Emission data were obtained from: Gordian Associates, Inc. *Environmental Impacts of Production of Virgin and Secondary Paper, Glass and Rubber Products.* Washington, U.S. Environmental Protection Agency, 1975. (In preparation.)

†Based on a 1-pound glass plate, averaged over 6,000 uses.

‡There may be some water pollution resulting from food particles left on the plates after scraping that are removed in the dishwasher. We were unable to get enough information to estimate the magnitude of this impact. In any case, food particles left on paper plates that are subsequently landfilled could end up in water sources through leaching and would be totally untreated.

The following describes these three approaches in terms of both resource and environmental benefits, and, where sufficient analysis has been completed, economic and social impact.

Product Charges

As described in the *Second Report to Congress,* product charges can be used to induce both waste reduction and resource recovery. These charges may be of value when two conditions exist. First, there must be a divergence between the private and social costs of production and consumption and, second, the administrative costs of implementing the product charge must not exceed the social benefits.

Generally, prices in a free-market economy allocate resources to maximize economic welfare. This will not occur, however, if the costs that a producer faces (private costs) understate the costs imposed on society (social costs).

For example, the private costs of packaging do not reflect the costs imposed on society in the collection, disposal, and litter cleanup of solid waste generated by packaging. Also, to the extent that environmental damages are not completely controlled, the environmental costs to the society incurred by direct materials use and indirect energy consumption and materials use are not reflected in the costs paid by the packager. Furthermore, the long-run value to society of all the resources used to make packaging may not be fully registered in the private costs of these resources, either because of ignorance of the effects of current consumption rates or because the demand of future generations is not felt in today's market.

The goal of a product charge would be to internalize these social costs at the point in the production process where decisions are made to maximize economic welfare. To the extent that internalization of social costs is feasible, the economy would become more efficient and would move toward the socially optimal level of waste reduction and resource recovery. Other benefits that might also result include improved balance of trade through reduced imports, and reduced environmental damages associated with production and waste management.

In order to obtain a better perspective on the costs and effectiveness of a product charge system, an analysis of the impact of product charges on the consumer packaging segment of municipal waste was carried out.

Scope of Study. The study evaluated the costs and effectiveness of Federal product taxes that may be used to influence the quantity and composition of consumer product packaging and the use of recycled materials in the manufacture of such packaging. Packaging was chosen to be reviewed because it is the largest single product class in the municipal waste stream, accounting for about one-third of all municipal waste. About two-thirds of the weight of all packaging waste is consumer product packaging (the remainder is shipping packaging such as corrugated boxes or pallets).

The analysis provides an initial basis for policy decisions regarding the desirability of product charges as a possible means for waste reduction and resource recovery. Other benefits that might result, such as natural resource savings, environmental savings, balance-of-trade improvements, and increased efficiency, are not included in the study. The administrative costs of the various options were also excluded.

Three consumer packaging tax schemes were selected for analysis:

1. A tax on the weight of consumer product packaging
2. A tax on the weight of consumer product packaging with an exemption for recycled materials (i.e., a tax only on the weight of virgin materials consumed in a package)
3. A per unit tax on all rigid containers used to package consumer products

The study concentrated on 30 consumer products and 9 packaging materials (Tables 16-18).

Study Findings. A summary of the estimated effectiveness and costs of the three types of product taxes at different rates is shown in Table 19. For each tax, the effectiveness increases as the tax rate increases. Among the three types of taxes, the per unit tax on containers induces the largest reductions in solid waste generation and energy utilization. The tax on packaging weight with an exemption for recycled materials leads to substantial increases in the recycling of post-consumer wastes and reduces consumption of raw materials. The tax on packaging by weight without the exemption has about the same effectiveness in reducing solid waste generation and energy utilization as the tax with an exemption, but the former is substantially less effective in reducing raw materials consumption and less effective in increasing the recycling of post-consumer wastes.

In order to gain some insight regarding the relative cost and effectiveness of different product taxes, cost-effectiveness ratios were calculated. The results show the cost (in terms of lost consumer surplus) per unit of effectiveness (reduced solid waste, reduced use of raw materials and energy, and increased recycling) for each type of product tax (Table 20). Only one average value for each type of tax was used since the ratios of costs to benefits are not very sensitive to changes in the rate.

TABLE 16

PACKAGING MATERIALS INCLUDED IN PACKAGING TAX STUDY

(Standard industrial code number in parentheses)

1. Flexible paper and paper closures
    - Waxed and oiled paper (26412)
    - Laminated paper (26415)
    - Bag paper (26431)
    - Glassine (2643)
    - Paper closures (26451/81)
2. Flexible plastics and plastic closures
    - Cellophane (2821)
    - Polyethylene (2821)
    - Polypropylene (2821)
    - Plastic sheet (2821)
    - Polystyrene and other thermoformed (2821)
    - Plastic closures (30794/71)
3. Metal closures
    - Metal caps (34616)
    - Metal crowns (34617)
4. Flexible aluminum
    - Aluminum foil—flexible (3352)
5. Rigid paper
    - Folding boxes (2651)
    - Setup boxes (2652)
    - Sanitary food board (2654)
    - Fibre cans, tubes (2655)
6. Rigid plastics
    - Plastic bottles (3079)
    - Plastic cups, jars, tubes, boxes, baskets (3079)
7. Glass
    - Jars (3221)
    - Refillable bottles (3221)
    - Nonrefillable bottles (3221)
8. Steel
    - Cans (3411)
    - Aerosol cans (3411)
9. Rigid aluminum
    - Aluminum plates (3352)
    - Cans (3411)
    - Collapsible tubes (3496)

The study did not consider the costs of administering or enforcing these product taxes, nor did it deal with distribution of the money after collection. It appears likely that a unit tax on packaging would have the lowest administrative and enforcement costs, while the packaging tax with an exemption for recycled materials would have the highest costs.

Deposit Systems

One mechanism that could be used to encourage product reuse is a deposit system. Deposits could apply to reusable products (e.g., refillable soft drink bottles or tires), or to other items that could be returned for recycling (e.g., an automobile deposit to decrease auto abandonment). Implementation of a deposit system would provide an economic incentive

TABLE 17

AMOUNTS OF NATURAL RESOURCES USED TO MANUFACTURE PACKAGING FOR CONSUMER PRODUCTS, 1970 (BASIC DATA FOR PACKAGING TAX STUDY)*

Packaging material	Natural resource	Amount
Paper	Raw materials (1,000 metric tons):	
	Wood pulp	6,406
	Chlorine	125
	Caustic	144
	Soda ash	77
	Sodium sulfate	317
	Lime	154
	Energy (equivalent million kWh)	23,497
Plastics	Raw materials (1,000 metric tons):	
	NLG feed stocks	1,766
	Field condensates	104
	Refinery feed stocks	1,082
	Energy (equivalent million kWh)	1,942
Glass	Raw materials (1,000 metric tons):	
	Glass sand	6,802
	Limestone	2,224
	Soda ash	2,214
	Feldspar	775
	Prepared saltcake	10
	Energy (equivalent million kWh)	26,334
Steel	Raw materials (1,000 metric tons):	
	Iron ore and agglomerates	5,905
	Coke	2,372
	Fluxes	1,360
	Mill cinder and scale	168
	Energy (equivalent million kWh)	19,374
Aluminum	Raw materials (1,000 metric tons):	
	Bauxite	2,266
	Lime makeup	62
	Soda ash makeup	250
	Petroleum coke	264
	Pitch	85
	Cryolite	22
	Aluminum trifluoride	13
	Energy (equivalent million kWh)	8,859
Total raw materials (1,000 metric tons)		40,685
Total energy (equivalent million kWh)		80,005

*Bingham, T. H., et al. [Research Triangle Institute]. An evaluation of the effectiveness and costs of regulatory and fiscal policy instruments on product packaging. Environmental Protection Publication SW-74c. Cincinnati, U.S. Environmental Protection Agency, 1974. 301 p.

TABLE 18

CONSUMER PRODUCT CATEGORIES INCLUDED IN PACKAGING TAX STUDY

A. Food and kindred products
  Perishables—
    1. Baked goods
      Bread and rolls; crackers and cookies; sweet goods
    2. Dairy products
      Cheese; eggs; milk; butter
    3. Frozen foods
      Ice cream; frozen desserts and baked goods; meat, fish, poultry; prepared foods; vegetables, fruits, juices, drinks
    4. Fresh and cured meat
    5. Fresh and cured fish and seafood
    6. Fresh and cured poultry
    7. Produce
  Beverages—
    8. Distilled spirits
    9. Wine
    10. Beer
    11. Soft drinks
    12. Prepared beverages
      Cocoa; coffee; tea; breakfast drinks
  Nonperishables and kindred products—
    13. Candy and chewing gum
    14. Canned foods
      Vegetables; meat, fish, and poultry; fruits and vegetables; soups; baby foods; juices and fruit drinks; milk
    15. Cereals, flour, and macaroni
    16. Pet foods
    17. Tobacco products
    18. Other foods

B. General merchandise
  Household supplies—
    19. Soaps and detergents
    20. Other cleaning supplies
      Dry cleaners; laundry supplies; waxes and polishes; other cleaners and cleansers
    21. Pesticides
    22. Other household supplies
  Health and beauty aids—
    23. Packaged medications
    24. Oral hygiene products
    25. Cosmetics and hand products
    26. Hair products
    27. Shaving products
    28. Other beauty aids
    29. Other health aids
  Other general merchandise—
    30. Other general merchandise

TABLE 19

SUMMARY OF THE EFFECTIVENESS AND COSTS OF THREE TYPES OF TAXES ON PRODUCT PACKAGING*

	Tax on packaging by weight (dollars per metric ton)				Tax on packaging by weight with exemption for recycled materials (dollars per metric ton)				Tax per container (cents)			
	$10	$22	$50	$100	$10	$22	$50	$100	0.5	1.0	1.5	2.0
Effectiveness:												
Reductions in solid waste generation (thousand metric tons)	201	441	988	1,930	198	395	783	1,402	1,549	2,317	2,766	3,183
Increases in the consumption of post-consumer waste materials (thousand metric tons)	0	0	0	0	3,894	5,911	8,742	9,703	0	0	0	0
Reductions in raw materials consumption (thousand metric tons)	273	597	1,348	2,627	4,880	7,660	12,688	15,744	1,950	3,019	3,719	4,413
Reductions in energy utilization (equivalent million kWh)	529	1,157	2,596	5,078	518	1,031	2,050	3,675	3,897	5,956	7,287	8,530
Cost (million dollars):												
Losses in consumer surplus†	0.4	1.9	9.7	36.5	31.5	59.5	148.8	236.6	10.7	41.7	93.8	166.5
Tax payments (million dollars)	273	597	1,337	2,582	237	472	913	1,670	1,651	3,138	4,622	6,073

*Bingham, T. H., et al. [Research Triangle Institute]. An evaluation of the effectiveness and costs of regulatory and fiscal policy instruments on product packaging. Environmental Protection Publication SW-74c. Cincinnati, U.S. Environmental Protection Agency, 1974. 301 p.

†"Consumer surplus" is defined as the difference between the price consumers would be willing to pay for a product and the actual market price of a product. A market price increase results in a "loss of consumer surplus."

to return a product to a central collection point so that it could be reused with minimal recovery costs. An economic disincentive would also be imposed on those who do not return the product. A deposit system can thus be thought of as a means of internalizing costs to society that are not presently accounted for by private costs (litter costs and solid waste management, environmental, and resource depletion impacts).

TABLE 20
SUMMARY OF THE COSTS (LOSSES IN CONSUMER SURPLUS) PER UNIT OF EFFECTIVENESS OF THE THREE TYPES OF TAXES ON PACKAGING*†

Measure of cost per unit of effectiveness	Amount of cost		
	Tax on packaging by weight	Tax on packaging by weight with an exemption for recycled materials	Tax per container
Dollars per metric ton of solid waste reduced	$2-19	$148-190	$7-52
Dollars per metric ton of increased use of post-consumer waste materials	–	8-24	–
Dollars per metric ton of reduced raw material use	1-14	6-15	5-38
Dollars per thousand kilowatt-hours of reduced energy use	1-7	57-73	3-20

*Bingham, et al. [Research Triangle Institute]. Effectiveness and costs of regulatory and fiscal policy instruments, 1974.
†Approximate values, not additive.

A great deal of public attention has been focused on deposit systems for beer and soft drink containers. In the *Second Report to Congress*, the impacts of deposit systems were presented in some detail. Data that have been accumulated since that report are presented here.

The mandatory deposit system proposed most often would require that all beer and carbonated soft drink containers carry a refund value, or deposit, of 5 cents. The retailer would be required to pay the deposit to the consumer for every empty container turned in. The retailer would be required to accept any empty container of any kind, size, and brand of beverage sold by that retail outlet. Retailers, in turn, could return empty containers to the distributor, who would also be required to pay the 5-cent refund.

Implementation of a deposit system would likely result in declines in beverage container litter and solid waste. Also, to the extent that the deposit results in a predominately refillable bottle system, there will be substantial savings in energy and materials and reductions in pollution. The environmental impacts from the current mix of beverage containers and from an all-refillable system were compared in Table 13. A comparison of current impacts with those from a system in which 90 percent of the containers are refillable is presented in Table 21.

Cost savings to the consumer are also likely to occur as a result of a shift to a largely refillable bottle system. This is because nonrefillable containers, which are more expensive to use than refillables, will be available only in small quantities. The effect of rising raw material prices is of significance here. During the past year, can prices rose an estimated 34 percent while refillable glass prices rose only 16 percent.[21] This has widened the gulf between the wholesale prices of beverages in refillable bottles and of those in cans. Even with the addition of a 1½-cent retail charge for handling the refillables, there is a clear price saving for the consumer, ranging from ½ to 3½ cents per container.*

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*EPA estimate based on data supplied by selected brewers and retailers.

TABLE 21
ENVIRONMENTAL IMPACTS FROM CURRENT MIX OF BEVERAGE CONTAINERS AND FROM A SYSTEM WITH 90 PERCENT REFILLABLES, BASED ON 1972 DATA*

	Current system	New system			Reductions	
		90% refillable	10% one-way	Total	Amount	Percent
Raw materials (million lb)	28,054	11,060	3,199	14,259	13,795	49
Energy (trillion Btu)	388	153	50	203	185	48
Water use (billion gal)	215	109	22	131	84	39
Industrial solid waste (million cu ft)	370	63	42	105	265	72
Atmosphere emissions (million lb)	1,616	668	210	878	738	46
Waterborne waste (million lb)	337	246	39	285	52	15
Post-consumer waste (million cu ft)	122	85	12	97	25	20

*EPA estimate based on data from: Hunt, R. G., et al. [Midwest Research Institute]. *Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives; Final Report.* v.1-2. Environmental Protection Publication SW-91c. Washington, U.S. Environmental Protection Agency, 1974. 178 p.

Implementation of a mandatory deposit system for beer and soft-drink containers would also have some penalties, however. Paramount among these is an employment dislocation. For although a deposit system is likely to create an estimated 60,800 jobs in the retail and distribution sectors of the economy, it is also likely to eliminate some 60,500 jobs in the container industries, and the jobs lost would be more skilled than those gained.

To offset these losses, it is recommended that a mandatory deposit system be phased in over time. Phasing in such a system by 1980, for example, would reduce the employment dislocations by 32 percent.[22] This would mean an average of less than 7,000 employees dislocated per year. Further reductions in unemployment could be achieved by an even more lengthy phase-in period. If, for example, a 90-percent refillable bottle market were to be achieved by 1985, an estimated 16,000 employees would be affected, less than 3,000 per year.[22]

On the basis of these data on environmental and economic effects, and in order to decrease the inequities arising from a patchwork of State and local legislation, John Quarles, Deputy Administrator of the U.S. Environmental Protection Agency, provided testimony to the Congress in May 1974 favoring the implementation of a nationwide mandatory deposit law for beverage containers, phased in over a substantial period of time.[23] EPA is currently carrying out an analysis of methods of phasing in a deposit system in order to minimize economic dislocations.

Voluntary Waste Reduction

Voluntary actions for waste reduction can be undertaken at either the producer or consumer level. Industries can redesign their products to conserve resources and reduce waste, and consumers can make purchases after considering the implications for waste of available product choices.

Current economic conditions have made voluntary waste reduction actions far more acceptable—and, for some individuals, necessary—than in the past. Consumers have become more cost conscious in their purchases. This has led to increased demands for larger package sizes and for durable goods that last longer. At the same time, rising energy and material costs have resulted in the redesigning of a number of products so as to require less material and energy in their manufacture. Indeed, it has been suggested that the quest for higher productivity may shift away from an effort to substitute energy for people toward an increased emphasis on what could be called materials and energy productivity. Obviously, such reorientation will benefit the environment as well as conserve resources.

This phenomenon of shifting priorities in the manufacturing industries has been noted throughout the recent literature. An article in *Business Week* has suggested the need for caution in relying exclusively on the private sector, however:

> For industry, the adjustment to high energy prices could reverse some long-standing practices. Some products may have to be redesigned for easy repair, easy recycling, and even longer life . . . [but] none of this will come about quickly, and some regulation may well be needed to shore up incentives for conservation if market forces prove too weak.[24]

Broad-scale intervention by the Government, on the other hand, should be viewed with extreme caution. Such intervention would have a profound impact on the market system because it involves direct control by the Federal Government of what has traditionally been a private market process. Some decisions regarding design changes could also potentially result in significant economic dislocations and job losses.

Voluntary programs seem to hold more promise, particularly at a time when there is a confluence of business, environmental, and consumer interests in the area of product design. EPA is now actively urging voluntary waste reduction and has established a program designed to focus industry efforts on product redesign for decreased material use.

REFERENCES

1. Kalina, J. F. Now it's seamless steel cans for food. *Modern Packaging,* 47(10):7-8, 16, Sept. 1974.
2. Late break; significant news as we go to press. *Modern Packaging,* 47(2):70, Feb. 1974.
3. Winning cartons with a luxury look. *Modern Packaging,* 47(5):42-43, May 1974.
4. Rule 41 will stay. *Modern Packaging,* 47(7):12, July 1974.
5. 1973/74 Automobile facts and figures. Detroit, Motor Vehicle Manufacturers Association, [1974]. 72 p.
6. Autos; Detroit struggles to think smaller. *Business Week,* (2348):147-149, Sept. 14, 1974.
7. Personal communication. A. T. Rhoads, Milk Industry Foundation, to M. Loube, Office of Solid Waste Management Programs, Resource Recovery Division.
8. Personal communication. J. Cannon, International Paper Company, to M. Loube, Office of Solid Waste Management Programs Resource Recovery Division.
9. Personal communication. Glass Container Manufacturers Institute and Brockway Glass Company to E. Claussen, Office of Solid Waste Management Programs, Resource Recovery Division.
10. Confidential industry correspondence.
11. Personal communication. M. Freidman, Owens-Illinois, Plastic Products Division, to H. Samtur, Office of Solid Waste Management Programs, Resource Recovery Division.
12. National Industrial Pollution Control Council. The disposal of major appliances. Washington, U.S. Government Printing Office, June 1971. 22 p.
13. RMA tire report; statistical highlights—December 1973. New York, Rubber Manufacturers Association, Feb. 19, 1974. 3 p.
14. Office of Solid Waste Management Programs, Resource Recovery Division. Unpublished data.
15. Westerman, R. R. The management of waste passenger car tires. Dissertation, University of Pennsylvania, Philadelphia, 1974. 239 p.
16. Motor vehicle distribution, production, and scrappage. Washington, U.S. Department of Transportation, Federal Highway Administration, Jan. 1973. 1 p. (Unpublished report.)
17. Dean, K. C., J. W Sterner, and E. G. Valdez. Effect of increasing plastics content on recycling of automobiles. Bureau of Mines Technical Progress Report 79. Washington, U.S. Department of the Interior, May 1974. 14 p.
18. Midwest Research Institute. Unpublished data collected under U.S. Environmental Protection Agency Contract No. 68-01-0793 (1974).
19. Personal communication. Single Service Institute to F. L. Smith, Jr., Office of Solid Waste Management Programs, Resource Recovery Division.
20. Personal communication. Gas Appliance Manufacturers Association to F. L. Smith, Jr., Office of Solid Waste Management Programs, Resource Recovery Division.
21. Personal communication. Glass Container Manufacturers Institute to E. Claussen, Office of Solid Waste Management Programs, Resource Recovery Division.
22. Bingham, T. H., et al. [Research Triangle Institute]. An evaluation of the effectiveness and costs of regulatory and fiscal policy instruments on product packaging. Environmental Protection Publication SW-74c. [Washington], U.S. Environmental Protection Agency, 1974. 301 p.

23. Quarles, J. R., Jr. Statement of Honorable John R. Quarles, Jr., Deputy Administrator, Environmental Protection Agency, before the Subcommittee on the Environment, Committee on Commerce, United States Senate, May 7, 1974. Cincinnati, U.S. Environmental Protection Agency, National Environmental Research Center, 1974. 14 p.

24. Shepard, S. G. Commentary; the end of the cowboy economy. *Business Week*, (2307):22, Nov. 24, 1973.

Chapter 3

ENERGY RECOVERY FROM POST-CONSUMER SOLID WASTE

The *Second Report to Congress* documented a turning point in resource recovery. When that report was prepared, techniques for recovering energy and materials from the waste stream were just beginning to be demonstrated on a large scale; and only a few communities were preparing to build systems.

The interval since then has witnessed the construction of three demonstration facilities (including EPA's energy recovery demonstration in Baltimore); the completion of the Nashville, Tennessee, district heating and cooling system; the start of construction of five full-scale, locally funded recovery systems; and the continued development and evaluation of EPA's demonstrations in Franklin, Ohio, and St. Louis, Missouri.

Today, as development of new technologies continues, the implementation of a resource recovery system has become for many communities a serious concern and a major activity. This *Third Report to Congress* presents a summary of resource recovery in the context of the progress that has been made over the past year.

This chapter presents estimates of the amount of energy potentially recoverable from solid waste, a description of the technology and of the markets for the recovered energy, and an evaluation of the availability of technology for energy recovery.

QUANTITY OF ENERGY POTENTIALLY RECOVERABLE

Theoretical Potential

In 1973, approximately 135 million tons per year of residential and commercial solid waste were generated. About 70 to 80 percent of this waste was combustible, having an average energy content of about 9 million British Thermal Units (Btu) per ton. Theoretically, if all solid waste in the U.S. had been converted into energy in 1973, about 1.2 quadrillion Btu per year would have been generated. This is equal to more than 564,000 barrels per day of oil equivalent (B/DOE) or 206 million barrels per year of oil equivalent (B/YOE). Growth in population and per capita waste generation would cause these figures to increase to 1,440 trillion Btu per year by 1980, or about 680,000 B/DOE or 248 million B/YOE. These and other findings are summarized in Table 22.

Available Potential

Not all waste is available for energy recovery. Energy recovery systems require large quantities of waste (at least 200 to 250 tons per day) delivered for processing at one site in order to achieve economies of scale. For this reason, energy recovery appears feasible only in more densely populated areas, such as most Standard Metropolitan Statistical Areas (SMSA's). If energy recovery had been practiced in all SMSA's in 1973, almost 900 trillion Btu would have been recovered. This is equal to more than 424,000 B/DOE, or 154 million B/YOE. By 1980, the energy potentially recoverable from the SMSA waste stream is projected to be about 1,085 trillion Btu per year, the equivalent of more than 512,000 B/DOE, or 187 million B/YOE.

Impact on Energy Demand

The quantity of energy potentially available from the waste stream of more densely populated areas (SMSA's) is significant. For example, the 424,000 barrels per day of oil equivalent that was available in SMSA's in 1973 is equal to:

4.6 percent of fuel consumed by all utilities in 1973 (9.2 million B/DOE)

Table 22

ENERGY POTENTIALLY RECOVERABLE FROM RESIDENTIAL AND COMMERCIAL SOLID WASTE*

	1973			1980		
	Btu† (trillion)	B/DOE‡ (thousand)	B/YOE§ (million)	Btu (trillion)	B/DOE (thousand)	B/YOE (million)
Theoretical	1,194	564	206	1,440	680	248
Available¶	899	424	154	1,085	512	187
Projected recovery	–	–	–	85	40	15

*These estimates are a function of (1) population; (2) the average amount of residential and commercial solid waste generated per person, and (3) the energy content of the waste (4,500 Btu per pound). The heating value of 4,500 Btu per pound (9 million Btu per ton) is generally accepted for "as received," unprocessed waste as delivered by a collection truck to a processing or disposal facility.

†Btu: British thermal unit.

‡B/DOE: Barrels per day of oil equivalent. (Assuming 5.8 million Btu per barrel of oil and 365 days per year.)

§B/YOE: Barrels per year of oil equivalent.

¶Based on all Standard Metropolitan Statistical Areas (SMSA's).

NOTE: Different waste processing methods have different recovery efficiencies. For example, a shredding/air classification waste processing system loses some potential energy by removing heavy combustibles from the fuel fraction, while high-temperature incineration with no prior classification would lose far less potential energy. However, no adjustment was made to allow for such processing losses or energy conversion efficiencies (of, say, steam or electricity) because no prejudgment can be made as to which energy recovery method would be used in any given situation.

10 percent of all the coal consumed by utilities in 1973 (4.1 million B/DOE)
28 percent of the oil projected to be delivered through the Alaskan pipeline (1.5 million B/DOE)
1 percent of all energy consumed in the United States in 1973 (35.6 million B/DOE)

The energy recoverable from SMSA's can light every home and office building in the country and is equivalent to twice the gasoline savings estimated for the 55-miles-per-hour fuel conservation program in 1973-74.

Perhaps more significant is the impact on energy needs of individual users. For example, many industrial plants can generate at least half the process steam they use from solid waste fuel, thus reducing dependence on fossil fuels.

Projected Implementations of Energy Recovery Systems

Based on energy recovery systems existing or planned at the present time, it is projected that by 1980 almost 30 cities and counties around the country should be operating the equivalent of about thirty-six 1,000-ton-per-day plants, recovering an estimated 85 trillion Btu per year, or 40,000 B/DOE, or 15 million B/YOE.

Effect of Paper Recycling on Energy Recovery

Wastepaper can be recycled as a fiber source, or it can be converted to energy. From a national perspective, recycling of wastepaper could reduce the amount of energy potentially recoverable from the waste stream by 5 to 10 percent or more, depending on the quantity and type of paper recycled. However, EPA studies show that existing paper recycling levels could be increased significantly without seriously affecting the fuel characteristics of the remaining solid waste.

Because these options–recycling or energy recovery–are mutually exclusive with respect to wastepaper at the time of disposal (although recycled paper can be converted to energy later), there can be a problem at the local level for those making decisions about resource recovery systems. The effect of recycling paper on the fuel value of solid waste varies with the level of recycling rates. If newspaper recycling efforts were increased to their maximum practical levels, the as-fired heating value, burn-out level, and sulfur content of the fuel would change by not more than 6 percent. If total paper recycling levels were doubled, the burn-out and sulfur content would change by less than 3 percent; the as-fired heating value would decrease by 9 percent; and the ash content would increase by 14 percent. Although paper recycling rates are far below their maximum practical levels at the present time, if such levels were approached, the effect on solid waste fuel characteristics would become more pronounced. Therefore, the design of energy recovery plants should take into account the effects of potential paper recycling levels.

TECHNOLOGY AND MARKETS

Many different approaches to recovering the energy value of solid waste are presently being examined. Waterwall incinerators are being used to generate steam in a number of U.S. cities. A new waterwall incinerator was constructed in Nashville, Tennessee, in mid-1974. A contract was signed in 1974 for the sale of steam produced at the Braintree, Massachusetts, incinerator. A waterwall incinerator to generate steam for industrial processing is under construction at Saugus, Massachusetts. In Baltimore, with financial support from an EPA solid waste demonstration grant, a pyrolysis system that will generate steam is beginning operation. EPA's St. Louis project is currently demonstrating a system that uses the shredded, combustible portion of solid waste as a coal substitute in a utility boiler. Chicago, Ames, Iowa, and Bridgeport, Connecticut, are building similar systems. Several other communities are considering similar systems and extension of the concept to oil-fired boilers, as well as use of wet-pulped or pelletized solid waste as a fuel.

Pyrolysis systems are being developed to convert solid waste into liquid and gaseous fuels. Two of these systems are the Garrett Research and Development Company's system for producing an oil-like fuel, which is being demonstrated with grant support from EPA in San Diego County, California, and Union Carbide's system for producing a gaseous fuel, which is being tested by that company at its plant in South Charleston, West Virginia. The recovery of methane from landfilled solid waste is being practiced at a pilot plant in Los Angeles and will be demonstrated at Mountain View, California, with grant support from EPA. Electrical power generation using a gas turbine is being explored in a research project conducted by the Combustion Power Company with EPA support.

These technologies enable solid waste to be converted into a number of different energy forms, including gaseous, liquid, and solid fuels as well as steam and electricity. The energy recovery system that should be employed in any particular community depends upon the market for the product.[1]

The market value of a solid waste energy product should be equivalent, on the basis of heat produced, to the value of the fuel which it replaces, less any additional costs incurred in its use. The current energy crunch has significantly increased the value of these products and has reduced the need to provide special incentives to enhance their marketability.

To be marketable, however, the solid waste energy products must have qualities acceptable to the user. Steam and electricity produced from solid waste are equivalent to those products from other sources, but fuels produced from solid wastes are physically and chemically different from their fossil fuel counterparts. Characteristics such as ash content, heat value, corrosiveness, viscosity, and moisture content have to be acceptable to the user. For all energy products derived from solid waste, such factors as reliability, quantity, and availability are also important.

The following is a review of the characteristics of the major energy products recoverable from solid waste, the status of technology for recovery, and the potential markets.

Solid, Liquid, and Gaseous Fuels

Solid, liquid, and gaseous fuels can be produced from solid waste by a number of systems currently under development. These fuels can be used as a supplement to their fossil fuel counterparts: coal, petroleum, and natural gas.

Mixed municipal solid waste has a heating value of approximately 4,500 Btu per pound. The heating value of solid waste is compared to that of fossil fuels in Table 23.

Systems for Producing Fuels. The technology for converting solid waste into fuel is very new but developing rapidly. All of the systems under consideration today were conceived of since 1968.

Prepared Solid Waste as a Supplemental Fuel. The city of St. Louis, with demonstration grant assistance from EPA, is producing a dry, shredded solid waste

Table 23

APPROXIMATE HEATING VALUE OF FUELS

Fuels	Heat value
Coal	8,000 to 14,000 Btu per pound
No. 6 heating oil	150,000 Btu per gallon
Natural gas	1,000 to 1,100 Btu per cubic foot
Municipal solid waste	4,500 Btu per pound

fuel which is used to supplement pulverized coal in an existing Union Electric Company suspension-fired boiler. Three hundred tons of solid waste fuel provides 10 percent of the energy used each day in the 125-megawatt boiler.

The process is divided into two distinct operations: fuel preparation and firing. A fuel transportation system is also required in St. Louis because the fuel is prepared 18 miles from the powerplant. At the processing plant, municipally collected solid waste is shredded in a horizontal hammermill and fed into an air classifier which separates the material into heavy (dense) and light fractions. The heavy fraction is passed over a magnetic belt to remove ferrous metals that are processed further before sale to the Granite City (Illinois) Steel Company for recycling. The light, mostly combustible material is stored temporarily in a bin and then loaded into 75-cubic-yard transfer trailers for the trip to the powerplant (Figure 1). At the powerplant the prepared fuel is transferred to a smaller bin from which it can be pneumatically blown into the boiler (Figure 2).[2-4]

More information on the St. Louis demonstration, including the results of the first series of air emission tests conducted as part of the project, is presented in the Appendix.

Similar systems are already being implemented in several other communities, even though the concept is still being tested. The Union Electric Company has announced a $70 million program to expand the demonstration operation to serve the entire metropolitan St. Louis area. In Ames, Iowa, a prepared solid waste fuel will be used in a municipally owned powerplant. In Chicago, it will be used by the Commonwealth Edison Company.

Various studies by EPA are investigating other possibilities for solid fuel prepared from solid waste: as a supplemental fuel in oil-fired boilers; preparation by a wet-pulping method; and pelletizing for use in grate-fired boilers.

Pyrolysis. Pyrolysis is the thermal decomposition of materials in the absence or near-absence of oxygen. The high temperature and the "starved-air" situation cause a breakdown of the materials into three parts: (1) a gas consisting primarily of hydrogen, methane, and carbon monoxide; (2) a liquid fuel that includes organic chemicals such as acetic acid, acetone, and methanol; (3) a char consisting of almost pure carbon, plus any glass, metal, or rock that may have been processed. The design of the individual system determines which of these outputs will be the predominant product.[5]

Two pyrolysis systems currently under development show promise of producing fuel of sufficient quality and yield to be marketable. The Garrett Research and Development Company's "Flash Pyrolysis" system, which is being demonstrated by EPA in San Diego County, California, will produce a liquid fuel. A gaseous fuel will be produced in a Union Carbide system that the Linde Division of the company is testing at its 200-ton-per-day test facility in South Charleston, West Virginia.

The demonstration plant for "Flash Pyrolysis" is expected to produce an oil-like liquid that will be used by the San Diego Gas and Electric Company as a supplemental fuel in an existing oil-fired boiler. This fuel, which is produced at the rate of 1 barrel per ton of solid waste, has a heating value of about 94,000 Btu per gallon, or about 65 percent of the heating value of No. 6 fuel oil on a volumetric basis. It has a higher moisture content and a higher viscosity than No. 6 oil.[6]

The Garrett process consists of a complex preparation system followed by a relatively simple pyrolysis reaction (Figure 3). To prepare the solid waste for the reactor, it must first be shredded. An air classifier then separates a light combustible fraction which, after being dried, is shredded again, this time to a particle size of one-sixteenth of an inch. This material is then introduced into the reactor, where it is mixed with hot, glowing char in an inert atmosphere. The material is pyrolyzed in less than a second, at a temperature of 900 F. The resulting gas is condensed to recover the oil. The process char is recirculated as the energy source to pyrolyze the incoming material.

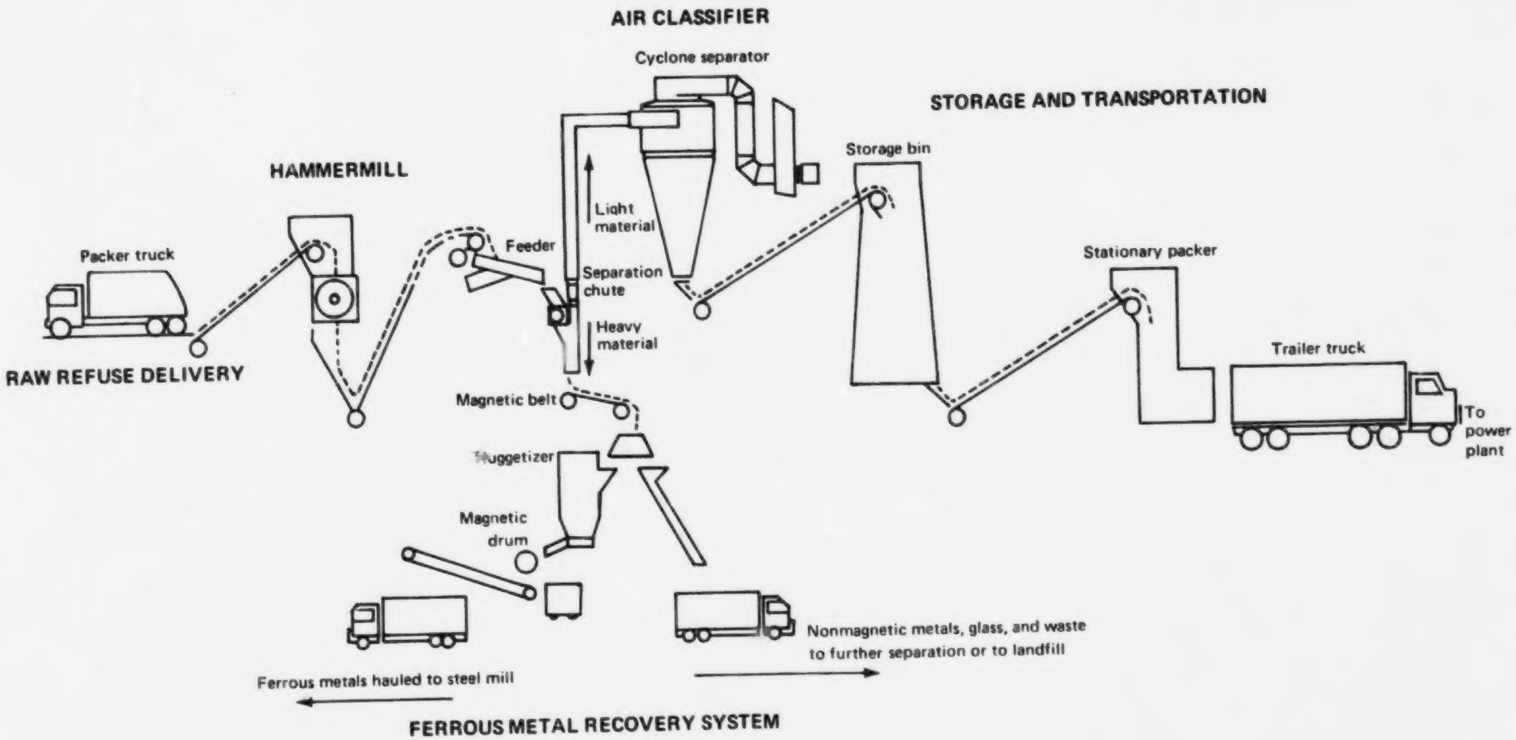

Figure 1. In the fuel-processing segment of the system being demonstrated by the city of St. Louis, the Union Electric Company, and EPA, fuel and ferrous metal are recovered from municipal solid waste that has been shredded and air-classified.

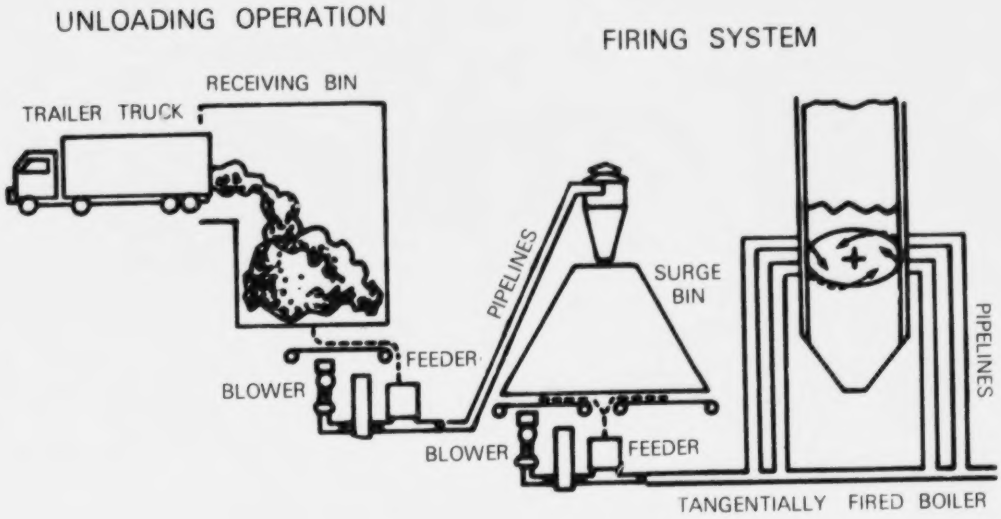

Figure 2. In the St. Louis project, the shredded solid waste fuel is delivered to the powerplant, where it is fired pneumatically into boilers as a supplement to coal.

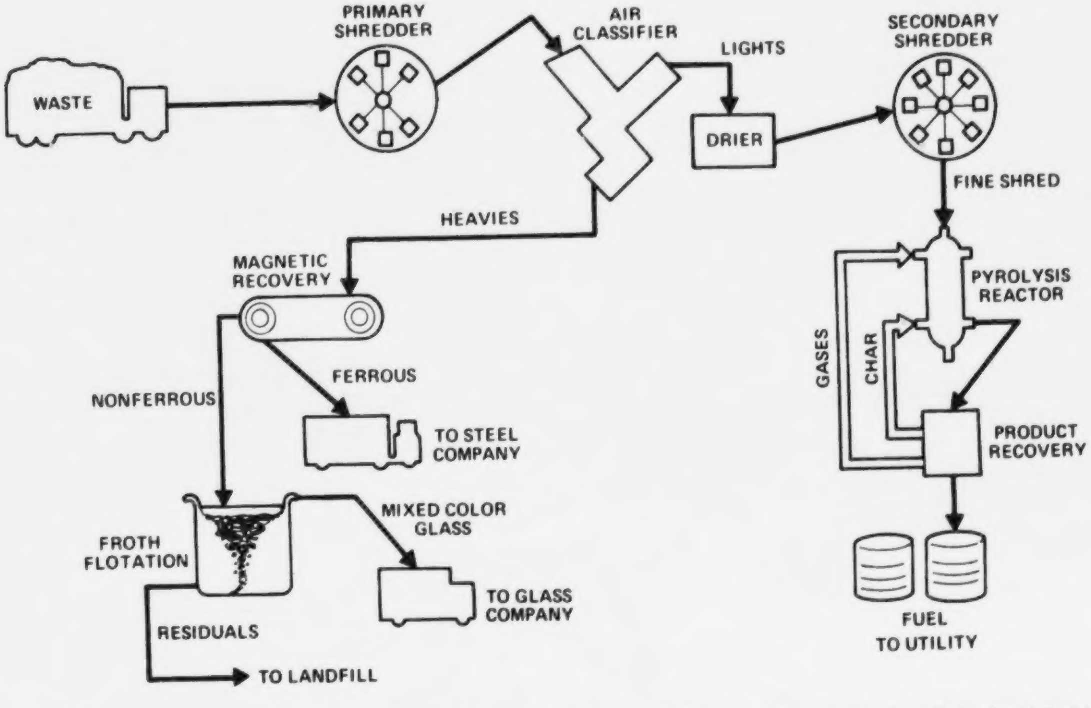

Figure 3. In the Garrett "Flash Pyrolysis" process being demonstrated in San Diego County, an oil-like liquid fuel is produced from solid waste. The fuel will be used by the San Diego Gas and Electric Company as a supplemental fuel in an existing oil-fired boiler. In addition to the fuel, ferrous metal and glass will be recovered.

More information on this EPA demonstration is presented in the Appendix.

The key element of the Union Carbide system is a vertical shaft furnace (Figure 4). Solid waste is fed into the top of the furnace. Oxygen entering at the base of the furnace reacts with the char that is one of the products ultimately formed from the solid waste. This reaction generates a temperature high enough to melt and fuse the ash, metal, and glass. This molten substance drains continuously into a water-filled tank, where it solidifies as a hard granular material.

The hot gases formed by reaction of the oxygen and char rise up through the column of solid waste and pyrolyze it, transforming it to gas and char. In the upper portion of the furnace, the hot gas also dries the incoming solid waste. The gases produced from the pyrolyzed solid waste exit the furnace at a temperature of about 200 F. This exhaust gas contains considerable water vapor, some oil mist, and minor amounts of other undesirable constituents, which are removed in a gas-cleaning system.

The resultant gas is a clean-burning fuel comparable to natural gas in combustion characteristics, but with a heating value of about 300 Btu per cubic foot, or about 30 percent of the heating value of natural gas. It is essentially free of sulfur compounds and nitrogen oxides and burns at approximately the same temperature as natural gas. This gas can be substituted for natural gas in an existing facility; the only plant modification necessary would be enlargement of the burner nozzle so that the volumetric flow rate could be increased.

One limitation on the use of this gas is the cost of compressing it for storage and shipment. Since a larger quantity of this gas is required to yield the same amount of energy as natural gas, compression costs per million Btu will be three times greater for it than for natural gas. Therefore markets for the gas should be within 2 miles of the producing facility, and only short-term storage can be contemplated.

Methane Production. When solid waste decomposes in an anaerobic (oxygen-free) environment, it

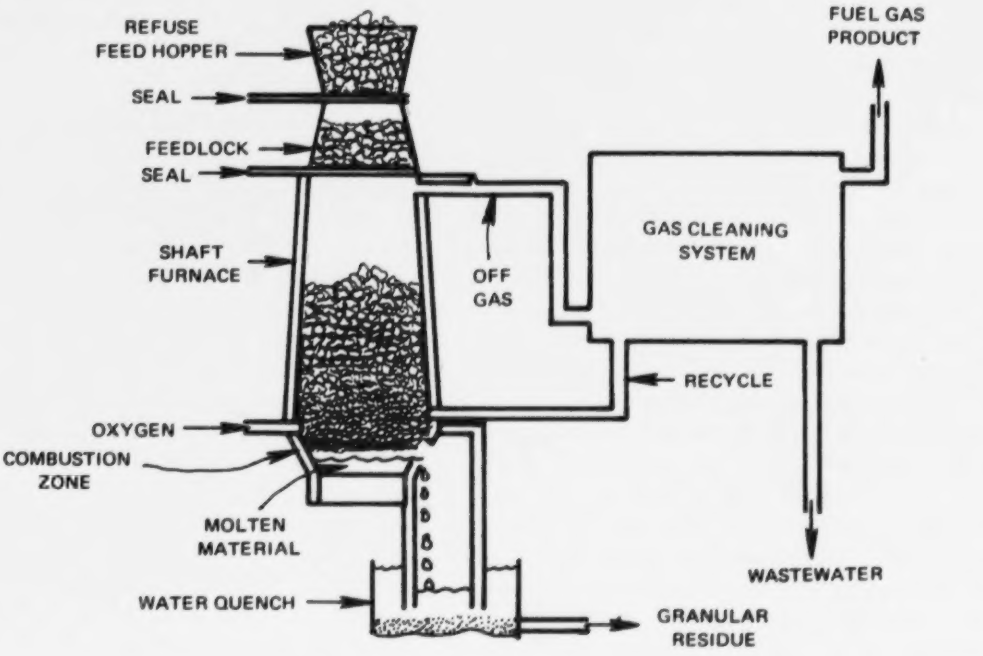

Figure 4. The key element of the Union Carbide pyrolysis process is a vertical shaft furnace. The fuel gas produced has about 30 percent of the heating value of natural gas but is otherwise comparable in combustion characteristics.

produces methane and carbon dioxide. Programs are currently underway to recover the methane that is produced by the natural decomposition of solid waste in a sanitary landfill and by the accelerated decomposition of solid waste in a mechanical digestor.

In the sanitary landfill recovery program, a well is drilled through the fill and lined with perforated pipe. The gases are pumped out of the fill, and the carbon dioxide is removed using membrane filtration or cryogenic separation techniques. A study and evaluation of this process is being conducted by the city of Mountain View, California, with funding by EPA. The NRG NuFuel Company is installing gas recovery systems in landfills operated by the county of Los Angeles and the city of Phoenix. Both of these sites possess very specific characteristics that are necessary for the process to be feasible. Any potential site must be examined to determine whether this process is practicable for the specific location.

The U.S. Energy Research and Development Administration is supporting the construction of a 50- to 100-ton-per-day pilot plant to produce methane through controlled anaerobic digestion of solid waste.

Potential Markets. Most markets for solid waste fuels will be either large utilities or industrial users that could blend 10 to 30 percent (by heating value) solid waste fuel with conventional fuels and still use sufficient quantities of solid waste fuels to justify the costs of special storage and firing facilities. Steam-electric powerplants, because of their large fuel needs and proximity to urban areas, represent an attractive market opportunity for solid waste fuels. Major industrial operations (such as cement plants, steelmills, and papermills) and district heating and cooling plants also represent potential market outlets.

Marketability. Fuels derived from municipal solid waste have different physical and chemical properties than conventional fuels and thus have different handling and combustion characteristics. In order to analyze the potential markets for these fuels, it is necessary to identify these characteristics and evaluate the constraints they will place on using the fuel products.

There are a number of general characteristics that determine the marketability of fuels derived from solid waste regardless of whether they are solid, liquid, or gaseous. These include heating value, quality, and quantity of the fuel produced, plus reliability of supply.

Solid fuels derived from solid waste are being used currently as a supplement to coal in suspension-fired utility boilers. They are also being considered for use in conjunction with oil-fired units and as a fuel supplement in cement kilns. Some factors that influence the marketability of solid fuels derived from solid waste are particle size, ash content, and moisture content.

Liquid fuel produced from solid waste through pyrolysis could be used as a supplement to No. 6 fuel oil in large industrial or utility boilers. Some factors that will influence its marketability include viscosity, heating value per unit of volume, chemical stability, and special handling requirements.

Most gaseous fuels produced from solid waste have a lower heating value than natural gas because they contain significant quantities of carbon dioxide and, in some systems, nitrogen. The distance over which they can be economically transported is limited by the cost of compressing and pumping. As the energy content per cubic foot decreases, transportation costs become increasingly significant in relation to the market value of the gas.

Steam Produced from Solid Waste

The most important properties of steam are temperature and pressure. Steam temperatures generally range from 250 F to 1,050 F, and pressures range from 150 to 3,500 pounds per square inch (psi). The strength of the materials used to construct the system places limitations on temperature and pressure. In electric powerplants the greatest efficiency is achieved at the highest temperatures and pressures. In steam distribution systems, temperatures are kept as low as possible to minimize heat loss in the delivery system and pressures are kept as low as possible to reduce cost and minimize danger from bursting pipes.

In systems that use solid waste as the sole or primary fuel, the steam is usually produced at 600 psi or less in order to minimize slagging and corrosion of the boiler tubes. The steam can be processed further in separate units to bring it to the pressure at which it will be used.

Available Systems. Systems available for the generation of steam from solid waste include waste-heat boilers, waterwall incinerators, and refuse-fired support boilers.

Waste-Heat Boilers. A waste-heat boiler package is one that is placed in the flue (exhaust gas passage) following the secondary combustion chamber of a conventional refractory-lined, mechanical grate incinerator. In addition to being used in many industrial processes, waste-heat boilers were used in the early design of heat recovery incinerators in this country. The poor operating characteristics of refractory-lined incinerators have made this approach generally obsolete.

A waste-heat boiler is employed quite effectively, however, as part of the new pyrolysis system being operated in Baltimore with EPA demonstration grant support.[7] The plant, designed by Monsanto, has the boiler following a pyrolysis kiln (Figure 5). Heat cannot be recovered from the kiln directly because it is used to accomplish the pyrolysis of the solid waste. Once the pyrolysis gases are formed, they are combusted in a separate afterburner. The heat that is released is recovered as steam using a package-type, waste-heat boiler. The system will generate 200,000 pounds per hour of steam from processing 1,000 tons of solid waste per day. The steam will be transmitted by pipeline three-fourths of a mile to an existing distribution system that is operated by the local utility. More information on this EPA demonstration is presented in the Appendix.

Waterwall Incinerators. Waterwall furnaces have almost entirely replaced refractory-lined combustion chambers in current incinerator design. In this type of construction, the furnace walls consist of vertically arranged metal tubes joined side-to-side with metal fins (braces). Radiant energy from the burning of solid waste is absorbed by water passing through the tubes. Additional boiler packages, located in the flue, control the conversion of this water to steam of a specified temperature and pressure.

This construction is also advantageous because it acts as an efficient method of controlling the temperature of the unit. The heat released by combustion is transferred to the water; consequently, less air is needed to keep the operating temperature of the incinerator at an acceptably low level. This, in turn, reduces the required size of the combustion unit, and thus the capacity of its air pollution control equipment has to be only about 25 percent that of equipment for an air-cooled, refractory unit. So effective is this means of temperature control that waterwall construction has become standard even in incinerators not designed for energy recovery.

In addition to the plants in Nashville, Saugus, and Braintree, waterwall incinerators are operating in Harrisburg, Pennsylvania, and Chicago. The steam generated by the latter plants is not being sold.

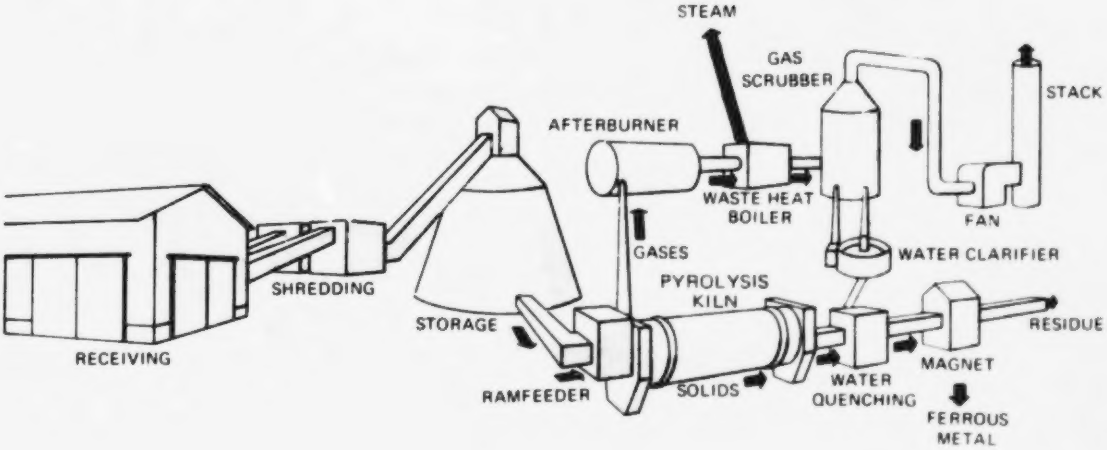

Figure 5. The Monsanto system being demonstrated in Baltimore recovers steam with a waste-heat boiler following the pyrolysis of municipal solid waste. The steam is to be used for downtown heating and cooling.

Solid-Waste-Fired Support Boilers. In Europe many municipalities combine waterwall solid-waste-fired units with separate fossil-fuel-fired units in one facility. Steam from the two separate units is integrated to drive one turbine generator system.

One reason this concept is widely applied in Europe but not at all in this country is that many European municipal governments, unlike most American counterparts, are responsible not only for solid waste disposal but also for power generation, distribution of steam for district heating, and the operation of electrically powered transportation systems.

Electricity Produced from Solid Waste

The systems described for producing fuel and steam can be extended to include power generation if the revenue produced from the sale of electricity is sufficiently high to offset the additional costs of the equipment needed to produce it. Like steam, electricity produced from solid waste would be indistinguishable from electricity produced by any conventional method.

The direct generation of electricity from solid waste combustion is being explored through a research project funded by EPA. The Combustion Power Company has developed a completely integrated solid waste combustion and power generation system known as the CPU-400 (Figure 6). A 100-ton-per-day pilot plant is currently in the development phase.

In this system, incoming municipal solid waste is shredded and air classified to remove noncombustibles. Metal and glass are separated for recovery. The combustible fraction is pneumatically transported to an intermediate storage facility and from there into a

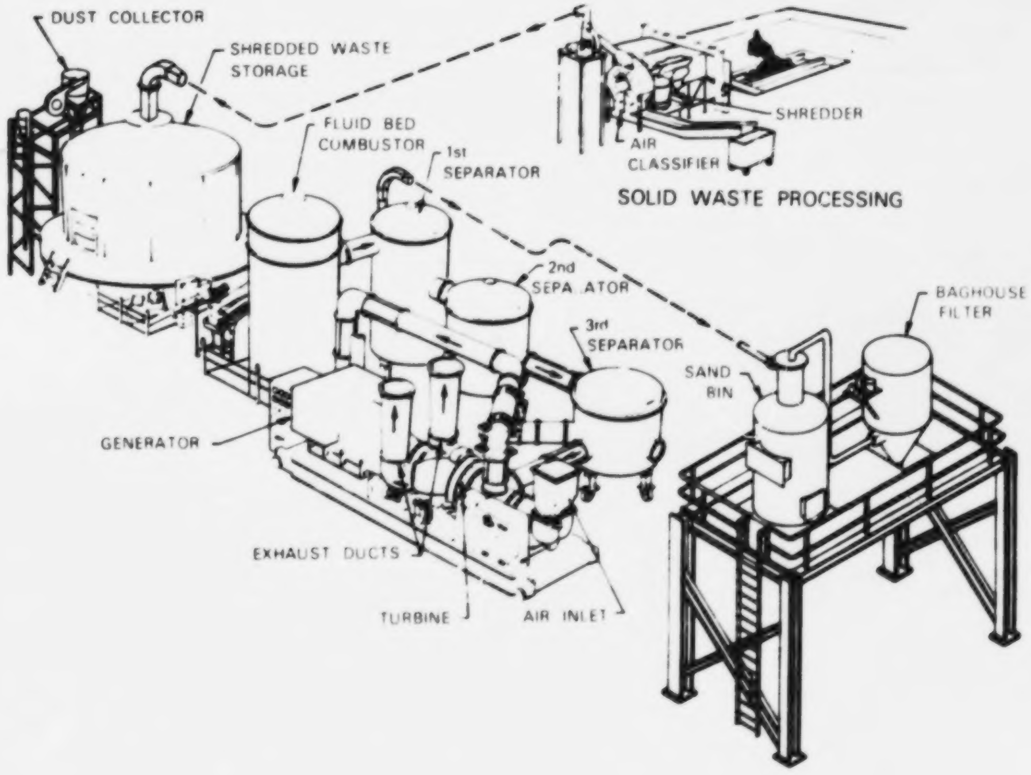

Figure 6. The CPU-400 pilot plant, developed by the Combustion Power Company and now in the development phase, generates electricity from solid waste by means of a gas turbine.

pressurized fluid bed combustor. The hot, high-pressure gases from the combustor pass through several stages of air-cleaning equipment (separators) to remove particulates. The cleaned gases are passed through a gas turbine that drives a 1,000-kilowatt generator. The pilot plant operates at only 45 pounds per square inch gauge (psig); commercial plants would operate at pressures in excess of 100 psig.

Performance problems have caused accelerated deterioration of the turbine blades and thus have slowed the development of this process. The deterioration and other problems must be solved before this approach becomes a technically and economically feasible system for energy recovery.

Another electrical generation concept, the burning of solid waste to generate steam to drive an electric turbine, has been proposed in several communities, including Hempstead, New York; and Dade County, Florida.

Potential Market. The major concern in marketing electricity is that it can be marketed only to the electric utility serving the area because, within that service area, the utility is generally exempt from competition. The only exception to that situation would be a municipally owned utility, but only a small fraction of the nation's electric generating capacity falls in this category.

The price that a utility will pay for electricity will depend upon whether it is used to satisfy base-load or peak-load demands. Peak-load electricity commands a much higher price than base-load, but it requires a much higher capital investment in equipment. A municipality would need to sell electricity on a continuous basis (i.e., as base-load) in order to maintain a continuous solid waste disposal operation at the lowest possible capital cost.

A municipality considering the sale of electricity to a utility could seek to establish a floating price for the electricity whereby the price would rise as the demand on the utility increased. The price would be a function of the incremental direct costs the utility would incur in producing the additional electricity.

Comparison of Energy Forms

The key to marketing energy from solid waste is producing a form of energy that can be sold and used without significant inconvenience to the user. In addition, the energy should be storable and transportable so that the solid waste facility can be built and operated independently of the energy market.

Steam and electricity satisfy the first objective but neither can be stored, and steam can be transported only very short distances.

The waste-derived solid and liquid fuels can be transported and can even be stored for brief periods of time (several days to several weeks). However, both fuels require the user to install special storing and firing facilities. In addition, the user must follow special handling procedures to minimize problems of air pollution and corrosion.

Waste-derived gaseous fuels are less likely to require special handling or need separate facilities for storage and firing, but those currently being produced cannot economically be compressed for extended storage and shipment. The best of the gaseous fuels cannot be shipped more than 2 miles.

EVALUATION OF AVAILABILITY OF TECHNOLOGY

Solid waste disposal systems must operate reliably and with a minimum of technical risk. Furthermore, the system must operate without degrading the environment and at a reasonable cost. Risk and reliability are usually evaluated through examination of existing, full-size systems in actual operation.

Although no energy recovery system is presently risk-free, two methods are commonly considered "commercially available." Other, possibly better, technologies are being developed and are projected to become commercially available throughout the 1977 to 1982 period.

Technologies Now Available

The technology that is now commercially available includes (1) the generation of steam (for district heating and cooling or for industrial processing) in a waterwall incinerator fueled solely by unprocessed solid waste and (2) the use of prepared (shredded and classified) solid waste as a supplement to pulverized coal in electric utility boilers. As noted earlier, there are already many waterwall incinerators in the United States. The use of prepared solid waste as a supplementary boiler fuel is being demonstrated in St. Louis and similar systems are being implemented by communities across the country, including: Chicago; Bridgeport, Connecticut; Ames, Iowa; Wilmington, Delaware (with EPA solid waste demonstration grant support); Monroe County, New York (Rochester area); and Milwaukee, Wisconsin.

These technologies are defined as commercially available because they have been demonstrated in large-scale facilities and because private industry is offering the systems for sale. While there is little risk of technical failure for waterwall incinerators, their long-term reliability has not been established. Solid waste has been used as a supplement to coal or oil in steam or steam-electric boilers in Europe for about 20 years. However, the practice is relatively new in the United States because most of our steam-electric boilers, unlike European boilers, fire fuels in suspension, and therefore the solid waste must be processed before it is fired as a supplementary fuel into the boiler. The St. Louis project has provided the only experience with this technology thus far. Until more systems are actually built and operated, there will continue to be some risk associated with their implementation. (See Chapter 6 for a discussion of the constraints to implementation of resource recovery systems.)

Technologies in Development

Other, possibly superior, technologies are being developed. Pyrolysis, which converts solid waste into gaseous or liquid fuels, is being demonstrated with EPA solid waste demonstration grant support in Baltimore and San Diego County, and without Federal support in South Charleston, West Virginia. These systems are expected to become fully operational during the 1977 to 1980 period.

In addition, the production of methane gas through controlled biological decomposition (anaerobic digestion) of solid waste is about to be performed at pilot-plant scale. Commercial implementation of this technology is projected to begin in the 1980 to 1982 period.

REFERENCES

1. Levy, S. J. Markets and technology for recovering energy from solid waste. Environmental Protection Publication SW-130. Washington, U.S. Environmental Protection Agency, 1974. 31 p.
2. Lowe, R. A. Energy recovery from waste; solid waste as supplementary fuel in power plant boilers. Environmental Protection Publication SW-36d.ii. Washington, U.S. Government Printing Office, 1973. 24 p.
3. Sutterfield, G. W. Refuse as a supplementary fuel for power plants; November 1973 through March 1974; interim progress report. Environmental Protection Publication SW-36d.iii. [Washington], U.S. Environmental Protection Agency, July 1974. 25 p.
4. Shannon, L. J., et al. St. Louis/Union Electric refuse firing demonstration air pollution test report. Washington, U.S. Environmental Protection Agency, 1974. 107 p.
5. Levy, S. J. Pyrolysis of municipal solid waste. *Waste Age*, 5(7):14-15, 17-20, Oct. 1974.
6. Levy, S. J. San Diego County demonstrates pyrolysis of solid waste to recover liquid fuel, metals, and glass. Environmental Protection Publication SW-80d.2. Washington, U.S. Government Printing Office, 1975. 27 p.
7. Sussman, D. B. Baltimore demonstrates gas pyrolysis; resource recovery from solid waste. Environmental Protection Publication SW-75d.i. Washington, U.S. Governmental Printing Office, 1975. 24 p.

Chapter 4

MATERIALS RECOVERY

The materials in municipal solid waste offer a significant potential for recovery and could contribute substantially to the material needs of this country. The *Second Report to Congress* discussed the fraction of total domestic consumption of various materials that could be supplied from municipal solid waste.[1] That report also discussed opportunities and constraints in recycling the waste components that are the prime candidates for recovery. These components together constitute 50 percent of the waste stream and include: paper (32.8 percent), steel (8.2 percent), glass (9.8 percent), and aluminum (0.7 percent) (Table 1).

This chapter discusses technical and economic factors affecting extraction, reprocessing, and reuse of these materials, with the major focus on developments over the past year.

PAPER RECOVERY

Background

Generation and Recovery. In 1973, 44.2 million tons of paper entered the solid waste stream and were disposed of, up sharply from 39 million tons in 1971 (Figure 7). This was 72 percent of the 61.4 million tons of paper and board (excluding the construction grades) consumed in the United States that year. The remaining 28 percent was either scrap generated in converting bulk paper and board into finished products (6 million tons), paper diverted from the solid waste stream such as tissue paper and file records (2 million tons), or paper recovered from the municipal waste stream (8.7 million tons).*

In total, 14 million tons of paper were recycled in 1973. Added to the 8.7 million tons recovered from post-consumer municipal solid waste was about 5 million tons of wastepaper recovered from the 6 million tons generated in industrial converting operations. The recovery rate for industrial converting operations was thus over 80 percent, but the post-consumer recovery rate was only 16.4 percent, which was nevertheless a slight increase over the 15.9 percent rate attained in 1971.

The traditional index used to measure the extent of wastepaper use is the ratio of wastepaper consumed domestically to total domestic consumption of paper and board—this is the "recycling rate." In 1973, the rate was 20.6 percent. There has been a steady decline in the recycling rate from the high of over 35 percent in 1944 (before that the rate had trended upward) to a low of 18.2 percent in 1972 (Table 24). For the last several years, however, the rate has ceased to decline, and preliminary 1973 statistics show a slight increase over 1972.

Recovery Potential. There were 44.2 million tons of paper disposed of as post-consumer solid waste in 1973. In evaluating the potential for further recovery, it is useful to examine the product structure of this paper that is not now being recovered (Table 25). The 44.2 million tons were composed of 8 million tons of newspapers, almost 12 million tons of corrugated containers, slightly less than 10 million tons of printing and writing papers, and almost 15 million tons of packaging or other grades.

The first three product groups are the primary categories for additional recovery because of their degree of concentration at the point of generation and the relative ease of separating them from other wastes. The estimated potential for recovery through source separation would indicate that, from a supply standpoint, it would be possible to double present

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***Based on data published in: *Statistics of Paper and Paperboard, 1974.* New York, American Paper Institute, July 1974. 70 p. Estimates of the fractions generated as industrial scrap, delayed or diverted, and recovered from municipal waste are from: Smith, F.L., Jr. *A Solid Waste Estimation Procedure; Material Flows Approach.* Environmental Protection Publication SW-147. [Washington], U.S. Environmental Protection Agency, May 1975. 56 p.**

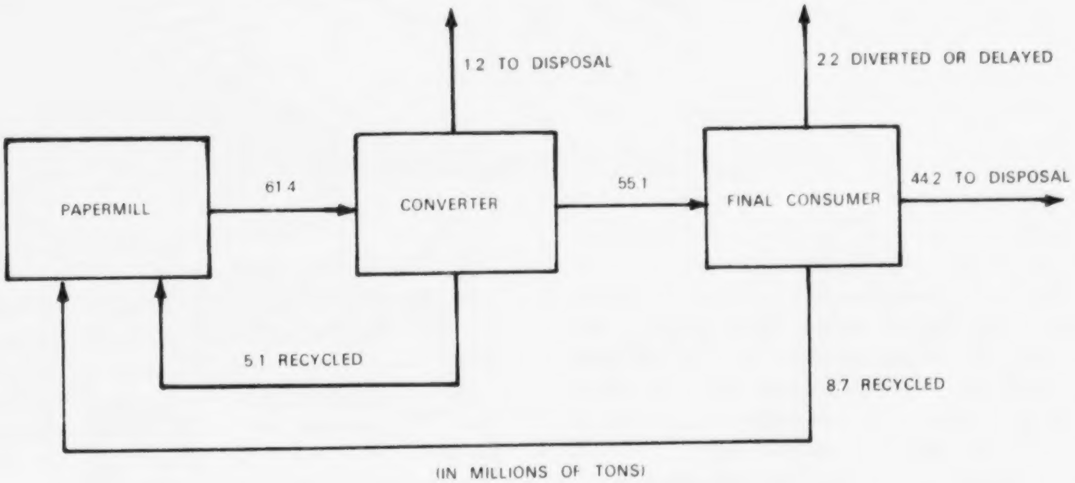

Figure 7. This shows the flow of paper from the mills through to disposal, estimated for 1973. Based on statistics compiled by the American Paper Institute as reported in *Statistics of Paper and Paperboard, 1974.* New York, American Paper Institute, July 1974. 70 p.

quantities of paper recovered without relying on new technology (Table 25). The market developments that would be required to consume this additional fiber are discussed later in this chapter.

Use of Wastepaper. The major portion of wastepaper consumption is in the domestic paper industry. Those paper or board mills consuming wastepaper can be divided into two types: the "dedicated" mill that relies on wastepaper for all or most of its fiber input, and the "supplemental-use" mill that uses wastepaper as a small fraction of its overall fiber furnish. For recycling to increase, either mills now using little wastepaper must increase their wastepaper consumption or new mills must be built that consume more secondary fiber than the mills now operating. That is, recycling can expand only if the industry intensifies its use of secondary fiber, either by changing existing operating practices or by investing in new secondary fiber mills.

The manufacture of tissue, recycled board, and construction paper and board consumes the major part of the wastepaper that is recycled, while very little goes into unbleached kraft packaging paper and kraft board (Table 26). High-grade wastepaper is consumed largely in the printing and writing or tissue categories. The bulk grades–news, corrugated, and mixed paper–are consumed mostly in the recycled board category. Another important market for corrugated is the production of semichemical corrugating medium. Corrugated wastepaper makes up about 20 percent of the fiber used in this sector. A market of increasing importance for old news is newsprint manufacture. Both old news and mixed paper are consumed in large quantities in the construction paper and board industries.

Changes in Paper Recycling in 1973 and 1974

Domestic Demand. Domestic wastepaper consumption increased by 9 percent or just under 1 million tons in 1973, according to statistics compiled by the American Paper Institute; the Bureau of Census estimates are slightly less (Table 27). This was the largest year-to-year percentage increase in many years. The largest increase by grade was for old corrugated containers–nearly 12 percent. Increases in other grades were more moderate. The pattern of increases by grade is consistent with that of the past several years, as Table 27 shows.

To place these increases in context, it is necessary to consider also the availability (potential supply) of each wastepaper grade. For example, although the recovered tonnages of news and corrugated have increased significantly, their respective recovery rates increased only slightly because of increased produc-

TABLE 24
DOMESTIC PAPER RECYCLING RATE: 1944 TO 1973

Year	Total paper consumption (1,000 tons)	Wastepaper consumption (1,000 tons)		Recycling rate based on—	
		Census data*	Industry data†	Census data	Industry data
1944	19,445	6,859		35.3	
1945	19,665	6,800		34.6	
1946	22,510	7,278		32.3	
1947	24,749	8,009		32.4	
1948	26,083	7,585		29.1	
1949	24,695	6,600		26.7	
1950	29,012	7,956		27.4	
1951	30,561	9,070		29.7	
1952	29,017	7,881		27.2	
1953	31,360	8,531		27.2	
1954	31,379	7,857		25.0	
1955	34,719	9,041		26.0	
1956	36,495	8,836		24.2	
1957	35,270	8,493		24.1	
1958	35,119	8,671		24.7	
1959	38,725	9,414		24.3	
1960	39,138	9,031		23.1	
1961	40,312	9,018		22.4	
1962	42,216	9,075		21.5	
1963	43,715	9,613		22.0	
1964	46,385	9,843		21.2	
1965	49,102	10,231		20.8	
1966	52,680	10,564		20.1	
1967	51,944	9,888		19.0	
1968	55,664	10,222		18.4	
1969	58,915	10,939	11,969	18.6	20.3
1970	57,940	10,594	11,800	18.3	20.4
1971	59,557	11,000	12,100	18.5	20.3
1972	64,386	11,703	12,915	18.2	20.1
1973	67,240	12,374	13,880	18.4	20.6

*U.S. Bureau of the Census. Pulp, paper, and board: 1973. Current Industrial Reports Series M26A(73)-13. Washington, U.S. Department of Commerce, 1975. 21 p.

†American Paper Institute, Statistics of paper and paperboard, 1974.

tion and the resulting increase in discards. The recovery rate of news has gone from about 19.8 percent to 20.6 percent over the period 1968-73, based on Bureau of the Census statistics. The recovery rate of corrugated has increased from 25.0 to 26.3 percent over the same period. Thus, the increased recycled tonnage achieved in 1973 did not substantially increase the recycling rate.

Indeed, the amount of paper entering the solid waste stream has increased steadily each year. For example, although corrugated recovery increased from 3.3 million tons in 1968 to 4.5 million tons in 1973, total consumption of corrugated products increased by over 5 million tons in the same period. As long as product consumption increases in this manner, recycled tonnages must increase rapidly in order to hold the recycling rate constant. Yet the recycling rate must increase if solid waste generation is to be held constant. As an illustration, the 1973 recycling rates for corrugated would have had to surpass the 1967 rate by 50 percent to keep corrugated wastes generation constant. The wastepa-

TABLE 25

POTENTIAL FOR ADDITIONAL RECOVERY OF PAPER FROM POST-CONSUMER SOLID WASTE THROUGH SOURCE SEPARATION, BY TYPE OF PAPER, 1973*

(In millions of tons)

Category of wastepaper	Paper disposed of		Potential recovery	
	Total	Urban areas	Percent	Amount
Newspaper	8.0	6.2	55-65	3.4-4.0
Corrugated	11.8	9.2	55-65	5.1-6.0
Printing/writing	9.7	7.6	30-40	2.3-3.0
Packaging and other	14.7	11.5	5-10	.6-1.2
Total	44.2	34.5		11.4-14.2

*The estimates in this table are based on statistics published by the American Paper Institute in their annual publication *Statistics of Paper and Paperboard, 1974.* The methodology employed is described in: Smith, F. L., Jr. *A Solid Waste Estimation Procedure; Material Flows Approach.* Environmental Protection Publication SW-147. [Washington], U.S. Environmental Protection Agency, May 1975. 56 p.

TABLE 26

END USES FOR WASTEPAPER, BY GRADE OF WASTEPAPER USED, 1973*

(In thousands of tons)

End product	Total U.S. production	Total wastepaper consumption	Grades of paper stock			
			Mixed paper	News-paper	Corru-gated	Pulp substitutes and high-grade deinked
Total paper:	26,750	2,870	317	594	140	1,938
Newsprint	3,430	490	17	482	–	–
Printing, writing, and related	13,500	938	44	–	–	893
Unbleached kraft pkg., industrial converting, special industrial, and other	5,840	263	47	14	15	187
Tissue	3,980	1,179	98	98	125	858
Total paperboard:	29,570	9,858	2,136	1,657	4,916	1,151
Unbleached kraft and solid bleached	17,430	449	50	1	355	44
Semichemical	4,260	849	77	19	747	7
Recycled	7,880	8,560	2,009	1,637	3,814	1,100
Construction paper and board, molded pulp, and other	5,700	1,591	919	327	235	109
Total	62,020	14,439	3,371	2,578	5,292	3,199
Percent distribution	–	100.0	23.5	17.2	37.0	22.3

*Capacity 1973-1976, with additional data for 1977-1979; paper, paperboard, woodpulp, fiber consumption. New York, American Paper Institute, 1974. 25 p.

TABLE 27
DOMESTIC WASTEPAPER CONSUMPTION BY GRADE, 1968-73
(In thousands of tons)

Year	Data source	Total	Mixed	News	Corrugated	High grades
1968	Census*	10,222	3,130	1,995	3,254	1,843
	Industry†	–	–	–	–	–
1969	Census	10,590	3,196	2,118	3,448	1,829
	Industry	–	–	–	–	–
1970	Census	10,594	3,140	2,073	3,511	1,870
	Industry	12,021	2,639	2,235	4,080	3,067
1971	Census	11,000	3,237	2,040	3,796	1,927
	Industry	12,323	2,776	2,174	4,277	3,097
1972	Census	11,703	3,393	2,118	4,244	1,949
	Industry	13,132	3,054	2,317	4,722	3,037
1973	Census	12,374	3,554	2,299	4,454	2,066
	Industry	14,439	3,371	2,578	5,292	3,199

*U.S. Bureau of the Census. Pulp, paper, and board. Current Industrial Reports Series M26A, [Section] 13. Washington, U.S. Department of Commerce, 1969-1974.

†The American Paper Institute's series *Capacity . . . Paper, Paperboard, Woodpulp, Fiber Consumption* for 1970 to 1973.

per market expansion that would be necessary for this did not occur.

Thus, the increased tonnages of recycled wastepaper in 1973 cannot be viewed with great optimism. Indeed, the markets for all paper grades have changed little over the last 4 years—the use patterns shown in Table 26 have remained essentially the same since these data were first collected in 1969. Although the total tonnage of secondary fiber used has grown, total paper and board production has also increased. As a result, the amount of wastepaper used per ton of paper produced has changed little.

Unfortunately the increased wastepaper demand of 1973 and early 1974 reversed in mid-1974 and decreased steadily. By the last quarter of 1974 monthly wastepaper consumption was well below comparable periods of a year earlier. Preliminary unofficial data suggested that, for 1974 as a whole, wastepaper consumption declined slightly in absolute tonnage from 1973.

Foreign Demand in 1973.[2] Exports historically have represented a small proportion of total wastepaper recovery in this country (Table 28). The percentage has increased from less than 2 percent in the early fifties to 5.2 percent in 1973, but the pattern has been erratic. In 1973, wastepaper exports increased by 65 percent after remaining essentially unchanged for the previous 3 years. This increase in exports accounted for about 20 percent of the total U.S. wastepaper recovery increase in 1973.

The impact of exports on domestic markets varies widely by region. By far the greatest impact of 1973 export increases occurred on the West Coast, where increased consumption by Asian countries sent export volume soaring. Seventy-four percent of the increased exports in 1973 occurred from the West Coast. Export increases in other regions were relatively minor by comparison. The regional importance of such export increases can be demonstrated by expressing regional exports as a percent of total regional wastepaper recovery (Figure 8). Exports were 16 percent of the total recovery on the West Coast in 1973 while in other regions they constituted only a small portion of total recovery.

In 1974 exports at first expanded rapidly and by midyear were double the amount for the corresponding period of 1973. However, in the latter half of the year, particularly the last quarter, exports dropped significantly. For the whole year exports totaled 1.3 million tons, 91 percent above 1973.

The future of exports is very difficult to predict; nonetheless, the increases of the past several years suggest that they may provide an expanding market for U.S. wastepaper.

TABLE 28
DOMESTIC CONSUMPTION AND EXPORTS OF WASTEPAPER, 1950-73
(In thousands of tons)

Year	Exports*	Domestic consumption†	Total recovery‡	Exports as percent of recovery
1950	120	7,596	7,716	1.6
1951	206	9,070	9,276	2.2
1952	142	7,881	8,023	1.8
1953	114	8,531	8,645	1.3
1954	126	7,857	7,983	1.6
1955	167	9,041	9,208	1.8
1956	190	8,836	9,026	2.1
1957	131	8,493	8,624	1.5
1958	107	8,671	8,778	1.2
1959	128	9,414	9,542	1.3
1960	153	9,032	9,185	1.7
1961	215	9,018	9,233	2.3
1962	209	9,075	9,284	2.3
1963	230	9,613	9,843	2.3
1964	272	9,843	10,115	2.7
1965	292	10,231	10,523	2.8
1966	246	10,564	10,810	2.3
1967	262	9,888	10,150	2.6
1968	253	10,222	10,475	2.4
1969	289	10,939	11,228	2.6
1970	408	10,594	11,002	3.7
1971	418	11,000	11,418	3.7
1972	413	11,703	12,116	3.4
1973	683	12,374	13,057	5.2

*U.S. Bureau of the Census. U.S. exports—domestic merchandise; (series) EM-522, sect. 2 (schedule B sect.). (Distributed by National Technical Information Service, Springfield, Va.)

†Statistics of paper. New York, American Paper Institute, 1964. 106 p. Statistics of paper and paperboard. New York, American Paper Institute, 1973. 70 p.

‡Preliminary Department of Commerce estimate, adjusted by EPA to reflect normal difference between preliminary and adjusted Commerce estimates.

Wastepaper Supply Changes in 1973. The wastepaper supply system exhibited severe fluctuations in 1973 as wastepaper exports increased dramatically, domestic use increased steadily, and alternate fiber sources, particularly market pulp, became scarce. Inventories of wastepaper decreased as firms faced increasingly tight supply markets; some mills even faced periodic production losses. These factors led to a very rapid rise in wastepaper prices to the highest levels since the Korean War (Figure 9).

This situation was viewed as a crisis in the industry. Considerable doubt was expressed as to whether the supply system could meet this increased demand. Extreme measures, such as curtailing exports, were advanced as short-term solutions to what was viewed as a failure of the supply system.

In retrospect, the response of the supply system to these price increases was very encouraging, especially when one considers the inevitable lag in expanding wastepaper supply that results from the need to arrange new collection agreements with waste generators and to add equipment to haul and process such material.

In Figure 9, the rise of wastepaper prices in 1973-74 indicates that demand grew more rapidly than supply in this period. However, supply appears to have expanded rapidly in response to these price signals. Declining wastepaper inventories were stabilized by the fall of 1973 and, within the next few months, rose to all-time highs.* This buildup was achieved despite increased demand from both domestic and export markets throughout the period and suggests a robust supply system. Prices soon stabilized, and then declined, apparently because inventories were replenished and supply again exceeded demand.

The major factor behind the *sharpness* of the rise and fall of wastepaper prices, however, was not the activity of wastepaper suppliers but rather the entry into and exit from the U.S. wastepaper market by domestic and foreign buyers who are generally not in that market. Their entry was a short-term response to the inadequate supply of virgin pulp in the 1973-74 period; wastepaper was their fiber of last resort.

The decreased wastepaper demand of the latter half of 1974, coupled with an overcharged supply system, caused wastepaper prices to fall to one-half to one-fourth those of early 1974, and once again made wastepaper recovery uneconomical for many potential supply sources.

EPA thus believes that paper recycling is limited by demand rather than supply. There is plenty of wastepaper available for recovery whenever a stable

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*National wastepaper inventories are reported in the *Monthly Statistical Summary* from the American Paper Institute in New York.

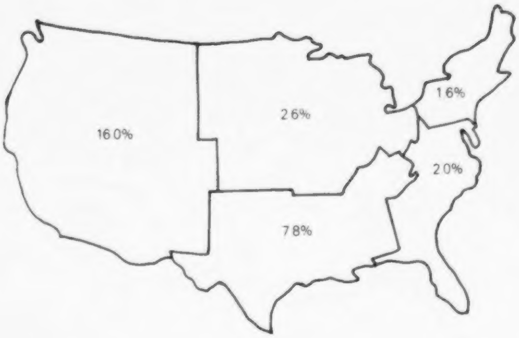

Figure 8. Wastepaper exports as a percent of total wastepaper recovery in 1973 are shown for the different sections of the country. The West Coast shows the greatest impact due to increasing consumption by Asian countries. Source: EPA calculations based on data in: U.S. Bureau of the Census. U.S. exports—domestic merchandise; (series) EM-522, sect. 2. (Distributed by National Technical Information Service, Springfield, Va.) *and* Capacity 1972-1975 with additional data for 1976-1978; paper, paperboard, wood pulp, fiber consumption. New York, American Paper Institute, 1973. 25 p.

market can be guaranteed. The problem is that the market expansion that would be necessary to provide such guarantees has not occurred.

Projections of Domestic Wastepaper Consumption

The future course of domestic wastepaper use is unclear. A positive sign is that manufacture of linerboard, a traditionally virgin fiber product, is projected to use increasing quantities of old corrugated as a fiber supplement through 1977. Use in this sector in 1973 increased by approximately 40 percent over 1972, a rate exceeding the expected growth in overall corrugated board production.[3] Another positive sign for use of old corrugated is that the capacity to produce combination medium, a grade within the recycled board category, is projected to increase by almost the same tonnage as the capacity to produce virgin medium over the next 4 years. This is a dramatic improvement over prior years during which virgin mills accounted for almost all growth in medium capacity. Capacity growth is also anticipated for mills producing newsprint from old newspapers.

There are also less favorable indications. Wastepaper use per ton of output in the construction paper and board sector is declining, apparently because construction paper—a large wastepaper consumer—is showing little growth in comparison with construction and insulation board—products using little or no wastepaper. This problem is exacerbated by the general slump in construction activity at the present time.

Capacity to produce combination folding boxboard, another grade within the recycled board category and one of the major markets for secondary fiber, is projected to grow more slowly than the capacity for producing virgin folding boxboard. This is a continuation of a trend of the past 10 years. Virgin boxboard production increased 50 percent from 1960 to 1973. In that period, combination boxboard production increased by only 3 percent.

These positive and negative indications together give a mixed view of the future. In the past, the failure of traditional markets to expand and of new markets to emerge has meant that the recycling rate would decline or, at best, remain constant. The level of wastepaper use projected in 1973 by the American Paper Institute in their annual capacity survey was encouraging. They estimated year-to-year increases as follows: 5.5 percent in 1974, 6.6 percent in 1975, and 6.4 percent in 1976; Table shows the projected wastepaper usage by grade. However, as noted earlier, the preliminary data for 1974 indicate a slight decline in wastepaper consumption. And if total paper and board production expand as anticipated, 6-percent annual increases in wastepaper use, should they be realized, would improve the recycling rate only slightly, and the quantity of paper in solid wastes would continue to grow.

Conclusions

The history of wastepaper markets prior to 1973 offered little hope for increased recycling. Thus, as reported in the *Second Report to Congress*, EPA evaluated several subsidies that might be employed to expand wastepaper demand. At the time of the writing of the *Second Report*—fall of 1973—the market expansion of 1973-74 was well underway and it appeared possible that the paper industry might have shifted permanently to more intensive use of wastepaper. In retrospect, it appears that few, if any, basic changes have yet occurred in the industry. Despite selective encouraging signs in some areas of wastepaper use, the overall market is still small relative to the potential supply. As a result, millions

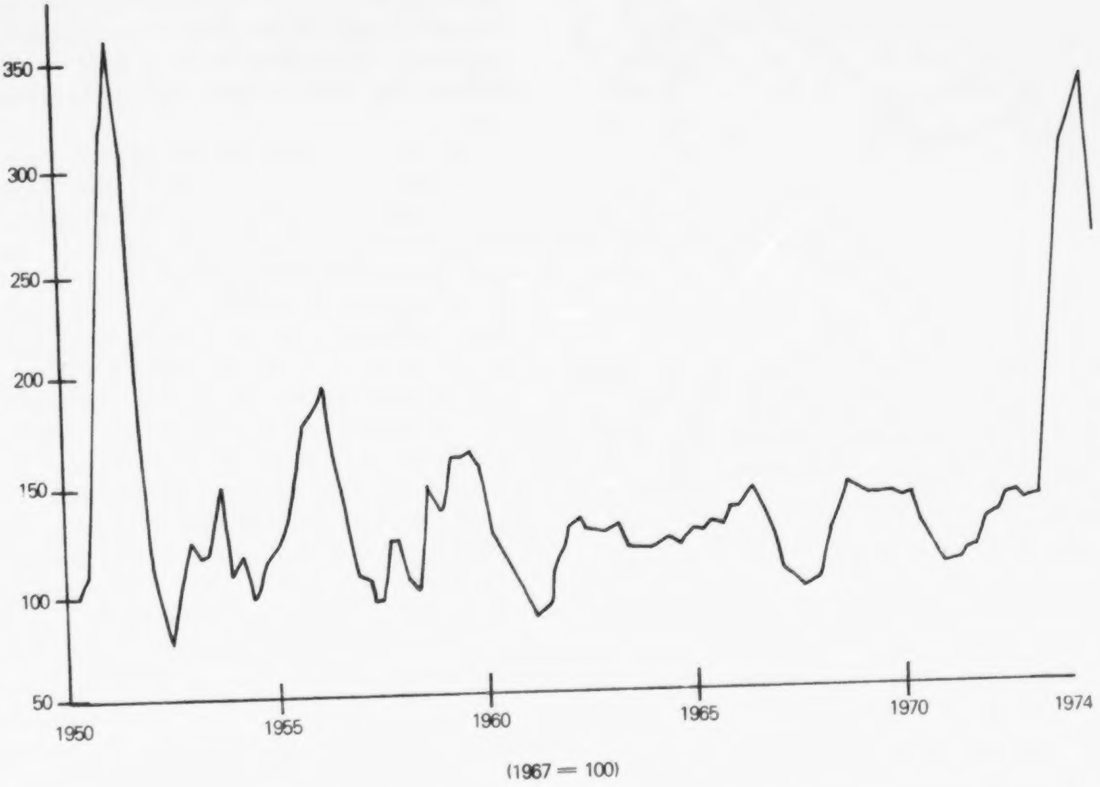

Figure 9. The wastepaper wholesale price index for 1950-74 shows a jump in price during 1973 and early 1974 to a level unprecedented since the time of the Korean War, followed by a steep drop in the latter part of 1974 because of decreased demand coupled with high inventories. Source: U.S. Bureau of Labor Statistics. Wholesale prices and price indexes. (Code 09-12: Wastepaper.)

TABLE 29
1973 PROJECTIONS OF WASTEPAPER CONSUMPTION IN 1973-77, BY GRADE*
(In thousands of tons)

	Wastepaper grades			
Year	Mixed papers	News-papers	Corru-gated	Pulp substitutes and high-grade deinked
1973	3,371	2,456	5,292	3,199
1974	3,522	2,504	5,796	3,281
1975	3,588	2,617	6,447	3,449
1976	3,739	2,711	7,095	3,569
1977	3,687	2,754	7,308	3,746

*American Paper Institute, Capacity 1972-1975, p. 20-21, 1973.

of additional tons of wastepaper will enter the solid waste stream each year for the foreseeable future.

The most appropriate form of Federal policy intervention to improve this situation has not been determined. The costs of each alternative, whether financial incentives, product charges, regulations, or even Federal example-setting, must be weighed against the benefits of greater recycling of paper. These alternatives will be evaluated over the coming year.

GROWTH OF SOURCE SEPARATION FOR PAPER RECOVERY

Source separation is the setting aside of recyclable waste materials at their point of generation by the generator. Separation is followed by the transporting of these materials to a secondary materials dealer or directly to a manufacturer. Transportation is provided either by the generator, by city collection vehicles, by private haulers and scrap dealers, or by voluntary recycling or service organizations.

Wastepaper has flowed back into the production cycle through source separation for decades. Charitable, service, and religious organizations have long been active in this area. In recent years they have been joined by thousands of recycling centers across the country. In the last 2 years, separate collection of news and mixed paper from homes, corrugated containers from commercial and industrial establishments, and high-grade papers from offices has increased dramatically.

Separate Newspaper Collection

Separate newspaper collection is the curbside collection of used newspapers on a regular basis by municipal or private waste collectors. Newspapers are kept separate from other waste in the household, bundled and tied, placed at the curb, and collected regularly like other solid wastes. In September 1974, there were 134 such programs in the country, according to an EPA telephone survey. The growth in number of programs was as follows:

Year	Number
1969	2
1970	6
1971	12
1972	37
1973	93
1974	134

Of the 134 programs, 55 percent utilized city collection forces and 45 percent were conducted by private contractors.

Two methods are presently used to collect the newspaper. In the first, separate trucks are dispatched to pick up newspaper only. They are usually regular compaction trucks, but open-bodied trucks can also be used. Of the existing programs, 85 percent employ this method; approximately half of these collect paper weekly, with the remainder equally divided between biweekly and monthly collections.

In the second method, metal compartments to store the newspaper are installed beneath the bodies of standard collection trucks. The newspaper and other refuse are collected simultaneously. This is the so-called "piggyback" or rack method of separate collection.

The success of separate newspaper collection programs depends heavily on four factors:

(1) *Available markets.* Markets must be available within a reasonable distance. They should be investigated in advance and assured by contract (39 percent of the participating communities have such contracts).

(2) *Publicity campaign.* Whether the program is mandatory or voluntary, citizen cooperation must be thoroughly solicited by making sure that citizens know of the program's existence and purpose and the exact nature of their requested participation. This requires an active publicity campaign.

(3) *Planning.* The changes in the existing collection procedures that will be required must be properly planned and carried out, including provisions for handling the newspaper after it is collected.

(4) *Antiscavenger ordinance.* A special ordinance may have to be drafted to prevent any party other than the municipal collection crew (or contracted private hauler) from picking up old newspapers when placed at the curb (about half the cities have such an ordinance).

Another key to success is the extent to which the program can be carried out with existing labor and equipment. At first glance, it would seem that additional equipment and personnel would be needed. However, of the cities now practicing separate collection, EPA knows of only three that have purchased new trucks for the program. Very few new employees have been hired because of separate collection, although the length of time spent on the collection routes by present employees has generally increased. In other words, most cities practicing separate collection have found underutilized equipment and labor to carry out the program and have thus increased the productivity of existing labor and equipment.

The equipment and labor costs of separate newspaper collection must be balanced against the proceeds from the sale of the newspaper and the savings in disposal costs.

Generalizations about costs or savings are difficult because of the city-to-city variation in the market price for old newspapers, disposal costs, type of collection used before and after initiation of separate collection, and other factors. Each community must estimate the economics under the conditions that exist in that community.

By the end of 1973, mills in many parts of the country were paying $50 to $60 per ton for baled newspaper. Discussions with municipal officials indicated that most municipalities were receiving $20 to $40, with an average of $32, from wastepaper dealers for loose newspaper. In the last half of 1974 and first quarter of 1975, paper prices declined. Buying prices of mills averaged near $15 per ton in December 1974. For the most part, industry has tried to maintain prices that allow city programs to break even, in order to keep this supply source viable.

Recent EPA case studies have examined the effect of separate collection (using separate trucks) and sale of newspaper on the collection costs of 10 communities.[4,5] (Table 30). In both the "before" and "after" cases, collection and disposal costs varied widely. However, the study results suggest an encouraging economic picture for separate news collection. When communities were averaging $25 per ton for newspapers, they were able to reduce their total collection and disposal costs by about 5 percent. Even when paper revenues were a low $8 per ton, the costs for the study communities, on the average, increased by only about 1.5 percent.

The participation rate–the percentage of households setting out their newspapers separated as requested–has an important bearing on system economics. It is of prime importance that as many householders cooperate as possible. Participation rates rise over time with a good publicity campaign. There are indications that participation rates in an ongoing program will rise above 50 percent on a purely voluntary basis. This is probably due in part to the desire of many citizens to contribute to environmental improvement. Furthermore very little extra effort is required to separate newspapers. An EPA study shows that only about 2.3 minutes per week of the householder's time is needed for extra handling of the newspapers.[4,5]

TABLE 30

IMPACT OF SEPARATE NEWSPAPER COLLECTION ON OVERALL RESIDENTIAL SOLID WASTE MANAGEMENT COSTS IN 10 CITIES (SEPARATE TRUCK METHOD)*

Case study location	Collection and disposal cost per ton prior to separate collection	Collection and disposal cost per ton after implementation of separate collection†			
		Low wastepaper price (average $8 per ton)		High wastepaper price (average $25 per ton)	
		Cost	% change	Cost	% change
Dallas, Texas	$12.10	$11.60	−4.1	$ 9.30	−23.1
Ft. Worth, Texas	13.50	14.10	+4.4	11.80	−12.6
Great Neck, N.Y.	36.00	38.70	+7.5	36.50	+1.4
Green Bay, Wis.	38.70	37.70	−2.6	37.10	−4.1
Greenbelt, Md.	27.20	27.40	+0.7	26.30	−3.3
Marblehead, Mass.	23.10	25.30	+9.5	24.10	+4.3
Newton, Mass.	32.40	32.20	−0.6	31.60	−2.5
University Park, Texas	14.70	14.90	+1.4	13.10	−10.9
Villa Park, Ill.	13.50	13.40	−0.8	12.40	−8.1
West Hartford, Conn.	26.30	26.50	+0.8	25.20	−5.7

*SCS Engineers, Inc. Analysis of source separate collection of recyclable solid waste; separate collection studies. Environmental Protection Publication SW-95c.1. U.S. Environmental Protection Agency, 1974. 157 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-239 775.)

†Credit given for diverted disposal costs and revenue generated from the sale of separately collected wastepaper.

Source Separation of Corrugated Paper

In contrast to newspapers, which are discarded primarily from residences, used corrugated containers are discarded primarily from commercial and industrial sources. Recovery from these sources has been practiced for many years and has been carried out primarily by wastepaper dealers rather than through volunteer channels. Some supermarkets and other commercial and industrial generators have separated and baled their corrugated containers, but waste haulers have also obtained large quantities in the past through hand separation of corrugated paper from other waste at disposal sites or processing stations.

In the past 2 to 4 years, source separation of corrugated paper has increased in importance. Most of the country's major supermarket chains now separate corrugated paper from other waste for recycling, as do many auto assembly plants and other commercial and industrial establishments. There are two major methods. The first is baling by the generator, using any of a number of techniques which differ in the size of bales produced, method of storage, and method of collection. Large bales are suitable for direct consumption by a papermill; small bales, generally under 500 to 700 pounds, have to be rebaled by a hauler or wastepaper dealer prior to shipment to a mill.

A second method depends on the use of stationary compactors–large metal containers attached to a stationary hydraulic ram–for storage of the corrugated. The hauler or wastepaper dealer empties the container and bales the corrugated paper. If the generator has mixed other waste with the corrugated paper, then hand-sorting must also be done. In the latter case, the generator has in fact done little or no source separation.

The method that is most attractive to a particular generator depends on the quantity of paper generated, the space available for handling the paper, and other factors. In a recent study of supermarket waste management practices sponsored by the U.S. Department of Agriculture, baling was found to be the most economically attractive method among large supermarkets for handling corrugated paper. Many large warehouses and large industrial generators also have found baling to be the most attractive approach. However, some other generators, such as large department stores, prefer stationary compactors, leaving the baling and perhaps the separation to the hauler.

Baling results in a higher price for the paper but generally requires more effort on the part of the generator. Use of compactors requires little change in normal waste discard procedures but results in less revenue for the paper.

The economic attractiveness to the generator of separation of corrugated is influenced by numerous factors, including quantity generated, type and size of store, method of regular waste storage and removal, type of separation system used, and local markets.

In 1973, market prices of corrugated at the mill rose to over $60 per ton in most parts of the country. Under these conditions many generators found the economics for separating corrugated to be very favorable. For example, many generators received enough revenue from separated corrugated to pay for the cost of a baler in a single year and, at the same time, reduce their waste-hauling costs. However, in 1974 prices dropped to less than half the 1973 level. Nevertheless, baling or otherwise separating corrugated paper continues to be a waste management technique of considerable appeal to many commercial generators.

Office Paper Recovery

Separation of high-grade office paper is the newest of the source separation phenomena and is growing rapidly. With the exception of computer tab cards and printout paper which, because of their high value, have usually been recycled, relatively little office paper has been source separated in the past. However, in the last 2 years, over 300 companies have implemented office paper separation programs. The majority of these systems utilize the desk-top tray or container into which each worker places his recyclable wastepaper.

Since most of the systems have been implemented only recently, EPA has developed little economic data on office paper recovery. Preliminary results indicate, however, that office paper separation is not only economically viable but quite profitable. Gains are derived both from revenue received for the paper and from disposal cost savings. For example, one major California firm reports that waste disposal quantities and costs have been reduced by one-third because of their highly successful office paper separation program. After 6 months of operation, a major aerospace manufacturer has received revenues of $250,000, experienced costs of only $55,000, and reintroduced some 2,500 tons of high-grade paper into the manufacturing cycle.

The potential for expanding office paper separation appears very favorable where programs can be properly planned and set up and publicity is continuous to keep employees motivated.

Conclusions

Source separation is presently the most feasible means of removing paper from the waste stream for recycling. Newspaper, corrugated containers, and certain types of papers from offices typically accumulate in relatively high concentration and homogeneous form at the points of generation. Their separation from other waste will usually be of only slight inconvenience to the generator and may result in savings to them in waste disposal costs.

The most significant new opportunities for source separation lie in municipal programs for source separation and separate collection of old newspapers from residences, in separation of corrugated containers by commercial and industrial establishments, and in separation of high-grade paper in offices. However, communities and businesses must consider markets and economics on a local basis.

STEEL CAN RECYCLING

Background

Ferrous materials constitute approximately 7 percent of municipal solid waste (excluding automobiles). About 50 percent of the ferrous fraction is steel cans. It is estimated that, in 1973, approximately 5.6 million tons of cans entered the solid waste stream. About 70 percent, 4.0 million tons, were generated in Standard Metropolitan Statistical Areas, where recovery is more likely to be economically feasible. The current rate of recovering cans from municipal solid waste is low. In 1973, approximately 70,000 tons of cans were recycled, less than 2 percent of discards.

Ferrous scrap is extracted from mixed solid waste magnetically. Magnetic separation can be carried out at landfill sites, incinerators, transfer stations, and comprehensive resource recovery facilities. To recover ferrous scrap suitable for most markets, the mixed waste must be shredded prior to magnetic separation. Although magnetic separation is gaining acceptance, EPA is aware of only 25 cities that are presently doing it. At least 18 additional facilities are planned.[6]

Developments in Markets for Post-Consumer Cans

The *Second Report to Congress* contained a description of the major markets for post-consumer cans as well as a definition of the supply potential.[7, p. 52-54] The copper precipitation industry was cited as the single largest user of scrap cans, accounting for 65 percent of all cans recovered in 1972. Two other industries, the steel industry and the detinning industry, were cited as having the most potential for growth in the consumption of scrap cans. The following will provide an update on these latter markets as well as the current status and techniques for recovering steel cans.

The Steel Industry. The steel industry represents the largest potential market for steel cans recovered from municipal waste. They can be used in both the blast furnace (where ore is reduced to iron) and also the basic oxygen and electric furnaces (where iron is refined into steel). In 1972, about 34 million tons of iron and steel scrap were purchased by the industry for use in steel manufacture. The 4 million tons of post-consumer cans generated in Standard Metropolitan Statistical Areas is equivalent to about 12 percent of this amount. Quantities of steel cans presently recovered are far below this rate of generation and are not great enough to use in steelmaking furnaces on a continuous basis.

Contaminants in scrap steel cans are a major barrier to their use in steel manufacture. The lead, tin, and aluminum present in can scrap may cause furnace damage or degrade the quality of the finished product. The seriousness of these contaminants is greatly reduced, however, if scrap cans are used as a small percentage of the total furnace charge.

The American Iron and Steel Institute's Committee of Tin Mill Products Producers has estimated that 5 percent of the scrap charge to the basic oxygen (steelmaking) furnace could be scrap cans.[8] This would be equivalent to 1.5 percent of the total steel produced or a potential demand of 3 million tons a year. This Committee has also stated that scrap cans could possibly replace about 5 percent of the iron ore in the blast furnace. Thus, the blast furnace and basic oxygen furnaces alone could consume more scrap cans than presently exist in municipal solid waste. Even large percentages of cans are acceptable in electric furnaces when relatively lower grade products such as reinforcing bars are being manufactured.

It is by no means obvious, however, that use of scrap steel cans in the manner described would actually occur even if sufficient quantities of recovered cans were available. Individual mills may be reluctant to use cans at these levels. Furthermore, there has been so little experience to date in use of cans in these ways that the viability of continuous use is difficult to assess at this time. Nevertheless some specification guidelines can be given. Scrap used in a basic oxygen furnace should be visibly free of plastics and contain less than 1 percent dirt and no more than 3 to 5 percent organics. A small amount of organics will burn off during the melting of the steel and therefore does not interfere with the steelmaking process. However, the organics do constitute an additional load on the air pollution equipment. Aluminum, lead, and tin are potentially troublesome but may not be a problem in the steelmaking process if sufficient hot metal (virgin iron) is available to dilute the elements. In addition, the scrap should be baled and have a minimum density of 70 pounds per cubic foot.

The recommended specifications for can scrap used for blast furnace feed include less than 1 percent dirt content and less than 2 percent loose organics. It should be in loose, free-flowing, balled form with a density in excess of 70 pounds per cubic foot.

The EPA demonstration of solid waste as a supplemental fuel in coal-fired utility boilers in St. Louis includes the extraction of ferrous materials from the solid waste. The recovered ferrous materials are being used in a blast furnace. This is the first instance in which scrap has been processed in a blast furnace other than for industry tests.

Quantities of cans presently recovered from municipal solid waste are too small to make an accurate assessment of the practical potential for use of recovered cans in the steel industry. The aluminum, lead, and tin content of cans is certainly undesirable even if it can be diluted. However, the undesirable contaminants can be reduced to an acceptable level by detinning. The resulting steel is a readily marketable, premium material classified as a No. 1 bundle, which in 1973 commanded a price of approximately $100 to $174 per ton.

The Detinning Industry. Detinning is a chemical process in which tin is recovered from tinplate. Most of the 3,000 tons of tin salvaged annually from scrap cans is extracted from scrap generated in can manufacturing plants. This is a reflection not only of low municipal recycling levels but also the difficult tolerance levels for contaminants in can scrap. The major contaminant in post-consumer can scrap is aluminum tops from bimetal beverage cans. This aluminum is not present in scrap from manufacturing plants. When present at levels greater than 4 percent, the aluminum undergoes a chemical reaction during detinning which causes foaming (boil-overs) and the production of hazardous hydrogen gases. Removal of the aluminum adds significant cost–approximately $10 per ton of cans processed–to the detinning process. Entrapped paper and other organics exceeding 5 percent may also be troublesome because they hinder the chemical reaction of the detinning solution with the tinplate.

Unlike the scrap for steelmaking, scrap cans for detinning should not be balled or otherwise flattened to a form that interferes with the access of the detinning solution to the tinplate surface or that does not allow easy drainage afterwards. This is an important consideration to the municipal official choosing a shredder for ferrous recovery. Incinerated cans are unacceptable because incinerators can cause the formation of oxides on the tinplate surface that are difficult to remove. The detinning industry is showing increased interest in post-consumer cans despite the contaminants. The industry has indicated possible interest in building detinning plants wherever 30,000 tons of can scrap are guaranteed yearly. Facilities processing 2,000 tons per day or more of municipal solid waste would probably produce enough scrap to meet this quota. The 1974 market value for can scrap for detinning ranged from $30 to $100 per ton, depending on quality of the material and geographical location. This value is up sharply from the 1971 figure of approximately $10 per ton.

Traditionally, detinning has been a batch, rather than a continuous, process. Fourteen detinning plants employing this process operate in the United States. They are located in Baltimore; East Chicago, Indiana; Elizabeth, New Jersey; Gary, Indiana; Gardena, California; Los Angeles, Milwaukee, Pittsburgh, San Francisco, and El Paso, Texas.

A new plant located in Wilmington, Delaware, is operating a continuous detinning process for the first time. The capacity of the plant is 200,000 tons of steel cans annually. The system includes a shredder, air classifier, and several separation and cleanup processes prior to detinning. It is capable of processing incinerator residues with aluminum content exceeding industry specifications, and organic content up to 7 percent. A major portion of the scrap cans going into this process comes from Delaware, Pennsylvania, and Maryland.

Ferrous Recovery Technology

Ferrous recovery technology is fairly well developed. Two approaches are the magnetic separation from incinerator residue and the magnetic separation from shredded municipal waste.

Incinerator Residue Recovery. This approach is presently being employed in Amarillo, Texas; Atlanta; Chicago; Melrose Park, Illinois; Stickney, Illinois; and Tampa, Florida. The recovered metal waste is separated and shipped to commercial shredders in preparation for sale to the copper industry or is sold directly for use in ferroalloy production. The difficulty with using incinerated waste is that often the ferrous material is altered by the high temperatures. Incinerators operating at lower temperatures (1,000 F to 1,400 F) will oxidize but not melt aluminum. At higher temperatures (1,400 F to 2,000 F), practically all the aluminum is melted off and removed, but most of the tin and copper are absorbed into the steel. Most incinerators operate at around 1,500 F to 1,700 F.

Recovery from Shredded Waste. This technology has been proven to be successful and is practiced in several locations around the country. The technology is relatively simple. Incoming municipal solid waste is passed through a shredder for size reduction and is then passed under a magnetic separator for removal of the ferrous fraction. Once extracted, the ferrous is cleaned by washing or air separation, magnetically separated again to reduce contamination, and compacted to increase density. Because of variations in specifications from industry to industry, it is extremely important that research on local ferrous markets be completed before a recovery system design is selected.

Economics

An excellent opportunity for ferrous material extraction exists wherever shredding of waste is required—to prepare waste for comprehensive materials and energy recovery plants; to reduce waste volume in order to extend landfill life; or to increase freight payloads at transfer stations.

Shredding of waste solely for ferrous material extraction is generally not economically feasible, however. At prices of $20 per ton for cans and $12 per ton for other miscellaneous ferrous materials, revenues from ferrous material extraction would total less than $1.25 per ton of refuse processed. Typical shredding costs exceed $1.25 per ton. However, in systems already using shredders for densification or recovery of other materials, the incremental costs of adding magnetic separation equipment should be easily covered by the revenues.

Impact of Beverage Container Legislation

Several types of legislative proposals to reduce generation of solid waste materials are being introduced in State and local legislatures. One of the more popular of these requires a mandatory deposit for beverage containers; this would have an impact on the amount of steel, aluminum, and glass containers discarded in the waste stream. Steel cans would probably be reduced by 15 percent and waste aluminum and glass by 30 to 35 percent, respectively. A 1,000-ton-per-day facility recovering ferrous scrap could realize a "yield loss" of approximately 2,000 tons of ferrous scrap a year. At a price of $20 per ton for scrap cans, the annual revenue losses would amount to $40,000. For each ton of raw waste input, revenue from ferrous materials extraction would be reduced from $1.25 to approximately $1.06. This decrease is not substantial. Most profitable ferrous recovery systems would remain profitable.

Conclusions

The copper precipitation industry consumes more than half the scrap steel cans reclaimed from solid waste. Consumption in detinning and steelmaking is increasing. Detinning offers the most potential for steel can recycling. It upgrades the cans to a form of high-grade steel scrap and recovers a valuable resource, tin, which would otherwise be considered a contaminant. Significantly, the economics of detinning plants are such that new small-scale plants could be built near cities or resource recovery plants where cans are generated.

Steel cans may contain tin, aluminum, or lead in addition to steel. The processes in both of the major potential uses of the cans, steel manufacture and detinning, are adversely affected by these other materials. So far, improvements in processing technology rather than changes in can design are being pursued by industry to improve scrap marketability.

ALUMINUM

In 1973, discards of aluminum into the municipal solid waste stream totaled 1.0 million tons, or 0.7 percent of the total solid waste stream. Half of the aluminum discards were cans, about one-third were foils, and the remainder was largely from major appliances.

About 34,000 tons of aluminum, or 3.5 percent of the amount discarded, were recovered in 1973. This tonnage consisted primarily of cans recovered through recycling collection centers, many of which are operated by the aluminum industry. Roughly 15 cents a pound is paid for aluminum cans brought to such centers. The Aluminum Association reports that about 17 percent of the all-aluminum cans produced in 1974 were recovered.

The future of aluminum recovery depends partly on the rate of expansion of the collection centers. It also depends a great deal on the development of technology to extract aluminum mechanically from solid waste and on the possible reduction of the aluminum content of waste as a result of legislation mandating deposits on beverage containers.

Another factor is the substantial variation in aluminum content of waste from State to State. About 78 percent of the aluminum cans are concentrated in five States: New York, California, Texas, Florida, and Washington.

Technology Developments

Three techniques being developed currently for mechanical recovery of aluminum are briefly described below. The techniques are eddy current separation, dense media separation, and electrostatic separation. These techniques are applied only to a small fraction of the input to a recovery plant, the heavier fraction of glass and metals that constitutes approximately 15 to 20 percent of the raw waste input. Several preconcentration steps, such as grinding, screening, and washing, are necessary to prepare the waste for these separation processes. It should be noted that aluminum separation and glass separation are usually combined into a single "module" since separation of either of these materials yields a fraction rich in the other.

Eddy Current Separation. In this procedure a waste stream rich in nonferrous metals is subjected to a time-varying magnetic field while moving along a conveyor. This produces an electromotive force that creates eddy currents within the nonferrous metals. The eddy currents create their own magnetic fluxes that oppose the original magnetic field, creating a repelling force. Nonmetallics are not repelled. Repulsion of the metals varies by type. Aluminum is repelled most strongly and, thus, is separated from the remaining materials. Initial tests suggest that the process is capable of yielding a product that is 90 to 97 percent aluminum. Eddy current separators are still in developmental stages and have not been used commercially. However, a commercial-scale test unit exists. In addition, a smaller unit is being evaluated at EPA's Franklin, Ohio, demonstration of glass and aluminum recovery. Test data are not yet available.

Dense Media Separation. This technique is based on the principle that elements making up solid waste have different densities and can be separated by sinking or floating in selected liquid media. The purity and types of materials recovered are determined by the original composition of waste being processed, the specific gravity of the media used, and the number of dense media stages applied.

Dense media separation is an established industrial process, but it has not yet been utilized in commercial operations for separation of aluminum or other materials from municipal solid waste. There are several commercial operations where dense media separation is being used to separate various nonferrous metals from shredded automobile scrap. This technique appears promising for application to municipal solid waste, particularly for larger scale systems.

Electrostatic Separation. In this separation method, waste materials moving along a conveyor are charged by means of an electrode. Wastes that have the physical property of conducting charges, such as metals, fall off the conveyor at the end of the belt in a normal fashion, while nonconductors (glass, rock, organics, etc.) maintain the charge and are pinned to the conveyor, much as the "static" in a sweater being taken off will cause it to cling to the body.

An electrostatic separator might be used in combination with dense media separation to make a final separation of a stream containing only glass and aluminum, or as a preconcentration step to separate and produce a glass-rich stream and a metals-rich stream, both of which would be processed further for purification of the products. An electrostatic separator is being used in EPA's Franklin demonstration to separate a glass-rich stream from a nonferrous metals stream. The glass stream is then put through a color-sorting process. The separate stream rich in nonferrous metal is channeled to an eddy current separation process. Test data are not yet available.

All of these new developments in technology are unproven at this stage, although all show a great deal of promise. The key question is whether they can separate out the aluminum at high levels of purity, yield, and throughput. The answers will ultimately determine the economic viability of aluminum separation.

Status of Aluminum Recovery Implementation

Although the economic viability of mechanical aluminum recovery is uncertain at present, there are plans to include it in some of the resource recovery facilities which will be built within the next 2 to 3 years. These include a dry separation resource recovery plant to be built in New Orleans in 1975 for recovering glass, metals, and paper; and a dry shredded fuel recovery facility in Bridgeport, Connecticut, scheduled to begin operation in 1976.

Impact of Beverage Container Legislation

A beverage container deposit would reduce aluminum content in waste by 30 percent, ferrous content by 15 percent, and glass content by 35 percent. For a 1,000-ton-per-day recovery plant, a reduction of 30 percent of the aluminum content would amount to roughly 300 to 400 tons per year of "yield loss" of aluminum, which, at $300 to $400 per ton, translates to $90,000 to $160,000 of lost revenue. On the basis of tonnage of raw waste input to the plant, a reduction in revenue of $0.34 to $0.61 per ton would be experienced. At this point, the economics of aluminum recovery are too uncertain to accurately judge the impact of such legislation on aluminum recovery feasibility.

GLASS

Glass accounts for approximately 9 percent by weight of total municipal solid waste. In 1973, over 13 million tons of glass products were discarded, and less than 3 percent, or 350,000 tons, were recovered and recycled.

The only technique currently being used for recovering glass is volunteer collection centers. The future of glass recovery naturally depends in part on the expansion of these collection centers; however, wide-scale recovery will probably not occur without new developments either in source separation and collection of glass or in new mechanical separation techniques.

Developments in Recovery Techniques

Source Separation. Home separation and collection of glass has been practiced only on a limited scale. However, a new and perhaps improved technique of separate collection involves the use of a two- or three-chambered vehicle which could collect glass, cans, and paper simultaneously. This technique has not yet been implemented and evaluated, but feasibility studies indicate that it should have significant advantages over use of the standard compaction truck. A key question regarding the success of this recovery technique concerns the willingness of residents to separate their waste into three or more components. There is only limited information on this subject at present.

Mechanical Separation. Most of the technology for mechanical separation of glass is still being tested; none has been proven. As noted in the previous section, glass recovery and aluminum recovery are natural complements; the recovery of one material usually renders a separate stream rich in the other. Therefore, aluminum and glass recovery are usually combined in one subsystem; the series of preconcentration steps preceding aluminum recovery would then be the same for glass recovery.

Three of the more promising mechanical processes being developed for the recovery of waste glass from municipal solid waste are the following:

Froth Flotation. Froth flotation has been used for several years by the mineral processing industry and can be applied to the recovery of glass cullet from municipal solid waste. To date, however, no commercial operations exist.

Froth flotation separation is based on the phenomena of surface chemistry of particles. A chemical compound is added to a tank containing a preconcentrated stream rich in finely ground glass suspended in water. The chemical adheres to the glass particles, creating a nonwetting surface property. Air bubbles are released from the bottom of the tank and become attached to the glass particles, causing them to float. Nonglass particles become wet and sink, thus providing the desired separation.

Although froth flotation techniques offer the advantages of a potential 95 percent recovery rate and high purity, it is uncertain whether the product can consistently meet the very stringent specifications which glass container manufacturers require. Another limitation is that the glass is not color-sorted—markets for mixed-color cullet are not as abundant as for color-sorted cullet. Froth-flotated glass cannot be color-sorted easily because the particles are generally too small to be separated efficiently.

Dense Media Separation. Dense media separation is based on the principle that materials of different densities can be separated by sinking or floating in selected liquid media. (See section on aluminum recovery.)

Many of the glass particles recovered in this process are large enough (3/16 to 2 inches) to make color-sorting possible.

There are presently no commercial operations where dense media separation of glass is taking place. However, a resource recovery facility now under construction in New Orleans will include dense media separation of a glass product that can be color-sorted.

Color-Sorting. A glass-rich concentrate containing 1/4- to 3/4-inch particles may be sorted by color. The concentrate would first be passed through a transparency sorting device for final removal of stones, ceramics, and residual metals. The glass would then pass through an electronic color-sorter in which a series of photocells match each glass particle with backgrounds corresponding with flint, amber, and green colors. Jets of air deflect the particles into appropriate receiving bins.

Color-sorting improves the marketability of recovered glass. However, this procedure is still in early stages of development and demonstration. Its feasibility is uncertain. The electronic transparency or color-sorting devices may require constant adjustment to perform properly. Organic residuals are apt to "cloud" or create a film on glass surfaces that often causes incorrect color or transparency readings. In addition, the method is limited to particle sizes of 1/4 to 3/4 inch, thus glass processed by froth flotation processes and some glass from dense media separation cannot be color-sorted. Another barrier to success is that processing losses of up to 50 percent may occur because shredding can break the glass into undersized particles.

In the Franklin demonstration project, an electrostatic separation process is producing a glass-rich stream that is fed into a color-sorting process. The color-sorting of mixed cullet has been operating since the fall of 1974. Adjustments to the sorting equipment are still being made.

Economics and Markets

Clean cullet is an attractive raw material. Demand exists at prices comparable to those for virgin materials. Color-mixed cullet is currently valued at $20 per ton. Color-sorted cullet may sell for more, depending on the market location. The real advantage to color-sorted glass is that there are at least twice as many markets for this material as for color-mixed glass. Almost all glass furnaces can utilize color-sorted glass, while only furnaces making colored glass can use color-mixed cullet. Potential markets exist for color-mixed glass in construction materials, such as foamed glass insulation or bricks, but these have not yet been developed to a significant degree.

Glass cullet is in some ways preferable to virgin raw materials because its use reduces fuel consumption and refractory wear. The glass industry generally limits the use of glass cullet in the glass formula to approximately 20 percent by weight, although 80 to 100 percent cullet formulations have been used.

The contaminants associated with color-mixed cullet removed from municipal solid waste includes the numerous color-formers (e.g., nickel oxides, iron, manganese, copper cobalt, elemental carbon). These chemicals produce a variety of colors that are difficult to control as the percent of cullet used increases. Also, inorganic contaminants that may be present (e.g., stones, rocks) will not flux. This causes defects in the glass product. Organic contaminants can act as reducing agents and cause color change of the melt.

Impact of Beverage Container Legislation

It is estimated that legislation requiring a deposit for beverage containers could result in a 35-percent reduction of glass in the solid waste stream. The impact on a 1,000-ton-per-day resource recovery plant could include yearly "losses" of approximately 5,000 tons of waste glass. At current market prices ($20 per ton), this reduction in glass recovery would represent $100,000 in revenue losses each year, or $0.40 per ton of raw waste processed. At this point, the impact of this loss on glass recovery feasibility is uncertain since the basic economics are not yet known with certainty.

REFERENCES

1. Resource conservation, environmental, and solid waste management issues. *In* U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; second report to Congress. Environmental Protection Publication SW-122. Washington, U.S. Government Printing Office, 1974. p. 1-18.
2. Smith, F. L., Jr. Trends in wastepaper exports and their effects on domestic markets. Environmental Protection Publication SW-132. [Washington], U.S. Environmental Protection Agency, 1974. 17 p.
3. Capacity 1973-1976, with additional data for 1977-1979; paper, paperboard, woodpulp, fiber consumption. New York, American Paper Institute, 1974. 25 p.
4. SCS Engineers, Inc. Analysis of source separate collection of recyclable solid waste; separate collection studies. Environmental Protection Publication SW-95c.1. U.S. Environmental Protection Agency, 1974. 157 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-239 775.)
5. SCS Engineers, Inc. Analysis of source separate collection of recyclable solid waste; collection center studies. Environmental Protection Publication SW-95c.2. U.S. Environmental Protection Agency, 1974. [75 p.] (Distributed by National Technical Information Service, Springfield, Va., as PB-239 776.)
6. Resource Technology Corporation. Solid waste processing facilities. Technical Report 103701, Rev. A. New York, American Iron and Steel Institute, May 1974.
7. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; second report to Congress. Environmental Protection Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p.
8. Progress report on recycling. Washington, American Iron and Steel Institute, Committee of Tin Mill Products Producers, [1974]. 8 p.

Chapter 5

RESOURCE RECOVERY PLANT COST ESTIMATES

Economic cost is a key factor in local government decisions to implement large-scale resource recovery plants. Cost is also likely to be a major consideration in formulating State and Federal policies regarding such implementation. Thus, it is very important that cost estimates for resource recovery plants be as reliable and comparable as possible.

Unfortunately, very little economic data are available. As of August 1975, no full-scale mixed-waste separation plants were yet in regular operation. In the absence of operating data, cost projections must be derived from preliminary estimates by consulting engineers and system development companies; these estimates are based upon experience with pilot-scale operations and price quotations by equipment suppliers.

A major problem in evaluating costs has been the general lack of comparability among cost estimates. There are two apparent causes for this. First, different cost-accounting methods are employed by various designers, making it difficult even to compare cost projections in proposals from companies bidding on the same contract. Secondly, most estimates have been site-specific, reflecting economic factors such as labor rates, operating schedules, and product costs that vary from place to place.

This chapter reports on the findings of a recent cost evaluation by EPA.[1] The first objective of the evaluation was to provide a better understanding of the site-specific variables that affect costs by developing a cost-accounting method to facilitate comparisons. The second objective was to provide meaningful cost estimates for one particular type of mixed-waste processing technology: the system based on two-stage shredding and air classification, similar in concept to EPA's demonstration plant in St. Louis but on a somewhat larger scale. Although generally considered in the fuel or energy recovery category of plants, this technology is also potentially adaptable to recovery of fiber for recycling. It may also be considered as a first-stage unit in an integrated steam or electricity generating facility.

The shredded-fuel system is only one of several material and energy recovery technologies being considered for implementation. Although the cost estimates presented in this chapter apply only to the specific technology under review, the cost evaluation methods and accounting procedures are generally applicable to all systems.

Following a brief introduction to the primary data sources, methods, and design assumptions, comparative results will be presented for capital investment costs, plant operating and maintenance costs, other special cost factors, product revenues, and a final synthesis of net processing costs for a number of recent shredded-fuel plant designs.

GENERAL METHODS AND DESIGN ASSUMPTIONS

What the Data Represent

The capital and operating cost estimates presented below are derived from a comparative review of five recent preliminary engineering designs. The plant designs selected are typical of improved versions of shredded-fuel plants patterned after EPA's St. Louis demonstration. The first of such "second generation" plants is scheduled to be on line by early 1976. All five could be considered to be either the medium (750 to 1,000 tons per day) or large (1,200 to 2,000 tons per day) size class by current standards.

The technical designs themselves were partially modified as necessary to reflect a more standardized "flowsheet" including: handsorting of paper, two-stage shredding (or milling) with one-stage air classification to produce a marketable fuel product, and magnetic separation of ferrous metals. Glass and aluminum recovery components were explicitly excluded due to insufficient data from most of the sources. In addition, original cost estimates were "normalized" to adjust for a number of differences among the original studies in terms of estimating methods, accounting formats, and site-specific cost factors.

The five original plant designs and cost estimates are attributable to the following sources.

1. The National Center for Resource Recovery (NCRR): an engineering feasibility study (December 1972)[2] as revised in the winter of 1973-74 in connection with a request for proposals for a plant to be constructed in New Orleans.[3] (The EPA modified version is referred to below as NCRR/EPA.)
2. Midwest Research Institute (MRI): a project for the Council on Environmental Quality, completed in the summer of 1972,[4] with estimates updated and revised during the autumn of 1973. (The modified version is referred to below as MRI/EPA.)
3. The General Electric Company (GE): a preliminary plant design prepared under contract with the Department of Environmental Protection, State of Connecticut, completed in the spring of 1973; hypothetically sited in Hartford, Connecticut.[5] (Modified version referred to as GE/EPA.)

4 and 5. Two confidential proposals actually submitted to a city in 1974. These two designs have been merged into a composite "Plant X" as a means of preserving the confidentiality of proprietary information. (Referred to as X/EPA.)

Before presenting the comparative cost results, further comments on the standard plant design and the issues in normalizing costs are necessary to define the scope and meaning of the estimates.

Standardizing the Plant Designs

Because some of the original plant designs varied considerably in terms of process and product-lines included, it was deemed necessary to standardize the designs for purposes of cost comparison. This involved either adding or subtracting building space and equipment items. The object was to standardize the basic processing sequence and "product lines" while preserving variations in original design conceptions such as structural plant features, throughput and storage capacities, number of primary process lines, and certain other special characteristics considered important by the original designers. After standardization, the designs still represented different conceptions of the same general type of resource recovery facility.

In order for the cost estimates to be meaningfully comparable, it is desirable to be able to standardize the technical assumptions or design conditions relating to plant capacity, annual operating schedule, and raw waste input composition. "Capacity" turns out to be a very ambiguous variable in the current design literature. For present purposes, the rated *hourly* design throughput tonnage is accepted as given by the original source. For a definition of *daily* design capacity, it was assumed that the plants will all operate on a full two-shift (16 hours per day) processing schedule. To facilitate calculating annual fixed costs per ton, *maximum annual* capacity was based on an assumed 5,000 hours of operation at average design capacity.* Differences in specifications regarding assumed number of hours per day and total hours per year for plant operation typically vary among designs of the same nominal capacity by a factor of two or more.

The estimates presented here also assume that the composition of the raw waste input at each plant is the same as the national average (Table 1, Chapter 1), and that the following recovery efficiency factors hold:

1. 25 percent efficiency in handpicking old news and corrugated
2. 90 percent efficiency in recovering organic material as fuel
3. 90 percent efficiency in recovering ferrous metal as steel scrap

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*Five thousand hours is roughly equivalent to 312 days per year (6 days per week times 52 weeks) times 16 hours per day. For a 1,000-ton-per-day plant (62.5 tons per hour times 16 hours per day), this implies a maximum annual capacity of 312,000 tons.

Normalizing the Cost and Revenue Estimates

In addition to technical design and operating features, a very large number of nontechnological variables and costing procedures also can have a strong influence on the estimates. To the extent feasible, these were also "normalized" to derive the present estimates.

This means that the design costs given in the original sources were recalculated on the basis of standardized prices and other costing assumptions. As noted below, a number of special cases were identified where a cost factor is both quite significant and variable over a wide range. For many of these, alternative calculations are presented to illustrate the particular influence of the variable at both high and low values.

The following notes describe the significance of these individual cost items and their treatment in the present context.

Items Affecting Capital Cost. These items affect either initial capital investment cost or annualized capital cost per ton.

1. *Land cost.* May or may not involve initial direct financing. May or may not be accounted for explicitly in engineering cost estimates. Could amount to a million dollars or more. For the evaluation, land cost was excluded from basic capital cost and included under "other special cost" items.
2. *Site preparation cost.* Extremely site specific. Demolition of existing structures could amount to several hundred thousands dollars. Site preparation was excluded from these capital cost estimates and treated separately with land.
3. *Regional construction cost differentials.* Direct capital costs typically vary among cities between 75 percent and 115 percent of the U.S. national average. Plant costs were adjusted to national average base using regional construction cost indices.
4. *Indirect construction contractor overheads and fees.* May or may not be explicitly included by different estimators. Can be 25 percent or more of direct construction costs. In addition, architect and engineering fees typically are 6 to 8 percent of direct costs. Adjusted to common basis where possible.
5. *"Contingencies."* May or may not be explicitly itemized in estimates. Included as a hedge against unforeseen circumstances in construction. Not a real cost unless some unforeseen circumstance materializes. Excludes labor and equipment cost escalations per se. May be 8 to 15 percent of total plant and equipment costs. Not possible to normalize on basis of available data.
6. *Construction cost escalations.* In effect, another type of contingency–estimated cost increases for labor, material, and equipment during construction period. Varies both with length of construction period and annual percentage increase assumed. Differences among estimating factors can cause multimillion dollar differences in capital cost estimates. Estimates for the evaluation were normalized by converting them to a common base period (January 1974).
7. *Plant startup and working capital.* May or may not be included. EPA estimates were normalized at 4 months of operating costs capitalized with other initial investment.

Items Affecting Operating and Maintenance Costs. O and M costs are defined here to include only direct, plant-related labor, parts, materials and supplies, and utilities. Other annual costs are included under "Other Special Costs."

1. *Regional price differentials.* Operating wage rates in different regions of the country can vary by more than ±15 percent of the national average. Electric utility rates can vary by a factor of more than 50 percent geographically; fuel prices per Btu can vary by a factor of three or more. The O and M cost figures presented here reflect conversions to national averages.
2. *Cost escalations.* These are calculated differently by different estimators; usually adjusted to first year of plant operation from base date of original quote. Differences in original date, projected startup date, and assumed rates of increases can mean a difference of over 50 percent in total O and M cost estimates among different sources. Standard base date of EPA normalized estimates was January 1974.

3. *Transport costs.* Costs of transporting recovered materials were accounted for here either in estimating net selling prices or in "other special cost" category. In various published sources, they have been included under general capital and O and M accounts or ignored altogether.

Other Special Costs of Operations. Five special cost items have been identified which, under various conditions, can each have values ranging from zero to over $1.00 per ton of raw waste processed (i.e., $300,000 per year based on a 1,000-ton-per-day plant operating 300 days per year). Such wide variations can be either locational or institutional in origin. "High" estimating options are indicated in the descriptions of these items below.

1. *Local property taxes.* Resource recovery facilities usually have been viewed in the same category as public waste disposal sites; property taxes seldom have been included in the cost accounts. Some State and regional systems do include an equivalent payment in lieu of taxes, based on assessed value.* An annual charge of 4.0 percent on total value of property was taken as a "high" cost factor in the comparisons below.
2. *Residual waste disposal costs.* About 20 percent of weight (perhaps 5 to 8 percent of volume) of raw waste input is not sold as product under present assumptions. If disposed of as waste, a disposal cost of $5.00 per ton was assumed to be "high" for this type of compact, shredded material (equivalent to $1.00 per ton of total raw waste input). At the other extreme, the glass and aluminum content of this fraction might make it marketable.
3. *Nonplant overheads.* These are costs chargeable to plant operation for off-site services by either a private or public sector central management agency. Could include bookkeeping, marketing, engineering or other functional services, or general overhead. For extreme comparisons, a range from zero to $1.00 per ton may be assumed.
4. *Management fees (profit).* Payable to private operator of a publicly owned or leased facility. (None for a publicly operated facility.) One dollar per ton of waste processed would seem to be a "high" fee (exclusive of corporate overhead expenses).
5. *Shredded product transportation costs.* Depending on who pays, could be accounted for as reduction in selling price. Treated here as separate item chargeable to shredding plant operation. For plants located adjacent to user's boiler, transport cost can approach zero. A "high" cost for reasonably long distances (say, 25 miles) would be $3.00 per ton of output material ($2.00 per ton raw wet input basis). Since this is a very large volume item, significant annual costs are involved.

Normalized Product Revenue Estimates. Given raw waste input composition and recovery efficiencies (discussed above) and assuming that markets for the recovered products are available, then product revenues will be determined by selling prices, less any relevant discounts and transport costs.

Product selling prices easily constitute the greatest source of uncertainty in the entire resource recovery picture. They exhibit the largest variations among geographic regions at any point in time and historically have been subject to extreme fluctuations. Future negotiable prices for recovered fuels and metals are subject to some additional uncertainties due to technical questions about product quality. (An important issue, not dealt with here, is the possible types of long-term contractual arrangements that may be developed with user-industries. These might eventually be able to dampen cyclical price fluctuations and also lead to higher product grade ratings than would otherwise be achievable in the general spot markets.)

For these reasons it was decided to develop new "high" and "low" product revenue estimates rather than use those found in the original source documents. The estimated revenue schedules are presented in Table 31. The basic assumptions and derivations of the values for the three products are summarized in the notes to that table.

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*The use of payments in lieu of taxes [illegible] also a means of reducing local prejudice against the location of a regional facility in a particular city. It is also a partial means of compensating a community for additional implicit costs such as increased truck traffic, noise, etc.

TABLE 31

NET PRICES RECEIVED PER TON OF PRODUCT AND REVENUE PER TON OF RAW WASTE PROCESSED: "HIGH" AND "LOW" ESTIMATES (1974)*

Product	Net price per ton of product output†		Recovered product as a percentage of total waste input (wet-weight basis)	Net revenue per ton of total waste input	
	"High"	"Low"		"High"	"Low"
Shredded fuel‡	$15.50	$ 2.50	67.0	$10.40	$1.70
Paper§	40.00	20.00	4.0	1.60	0.80
Ferrous metal¶	50.00	12.00	7.7	3.85	0.90
Total	–	–	78.7	$15.85	$3.40

*U.S. EPA estimates, Office of Solid Waste Management Programs, Resource Recovery Division.

†Prices received by seller net of transport or other discounts.

‡Based on Btu value of shredded fuel at 10 million Btu per ton, 30 percent moisture, less $2.50 per ton estimated firing cost to user. "High" net price based on $18.00 per ton of fuel (equivalent to $1.80 per million Btu average U.S. contract price for utility grade residual fuel oil in spring, 1974). "Low" price based on $5.00 per ton of fuel (equivalent to coal at $0.50 per million Btu or $11.00 per ton), less $2.50 firing cost.

§Average combined prices of old news and corrugated, F.O.B recovery plant, assuming buyer pays freight. "High" $40.00 price is U.S. average in spring, 1974. "Low" $20.00 price is U.S. average in winter of 1972-73. *Official Board Markets* quotes.

¶Average scrap steel grade better than No. 2 Bundle grade, less $10.00 per ton freight paid by seller. Gross "high" price of $60.00 is spring, 1974, U.S. average. Gross "low" price of $22.00 is winter, 1973, U.S. average. *American Metal Market* quotes.

The prices for both ferrous and paper are stated as values received by the seller (processing plant) net of all transport charges. Shredded fuel prices, however, are defined net of a powerplant firing cost discount (assumed at $2.50 per ton of fuel) but without deducting costs of transporting the shredded fuel to the powerplant. As previously noted, because it can be such a large and variable element, the cost of transporting the fuel has been singled out for special note under the "other special costs" category.

The net product selling prices are combined in Table 31 with the product-yield assumptions to calculate revenue per ton of total raw waste input. Thus, adding all the "high" product estimates results in a total maximum revenue of $15.85 per ton of waste processed. This contrasts sharply with the minimum total revenue receivable under the present assumptions of $3.40 per ton of waste processed.

It should be emphasized that the "high" and "low" estimates represent neither the maximum nor the minimum conceivable under all present or future circumstances. Rather, they simply represent the results of a combined assessment of assumptions relating to product grading (quality) specifications, current U.S. average fuel prices, and material prices experienced within the past 2 years. The estimates assume no future increase in prices, but the low values assume that wastepaper and steel scrap prices will not fall very much below their lowest levels of the past 2 years. The true worst case is where no market exists for the shredded fuel or other product.

COMPARATIVE SUMMARY OF NORMALIZED CAPITAL INVESTMENT COST ESTIMATES

Total Capital Cost

The total capital investment costs in Table 32 reflect both the flowsheet revisions and the cost-estimating revisions previously discussed. Otherwise, they continue to reflect the differences in design conception of the original design teams.

The normalized estimates exhibit a much closer grouping of values than the original capital cost figures. However, remaining differences in capital cost, especially those between the GE and NCRR plants, may still seem surprisingly large to many readers.

Although all the differences among the estimates could not be explained on the basis of available documentation, most of the $8.8 million difference between the normalized GE and NCRR capital cost is readily attributable to technical and architectural design differences. For example, the GE design has

TABLE 32
NORMALIZED CAPITAL INVESTMENT COST ESTIMATES FOR FOUR DRY-SHREDDED-FUEL PROCESSING PLANT DESIGNS*†

Plant capacity and investment cost measures	NCRR/EPA	MRI/EPA	GE/EPA	X/EPA
Plant capacity factors:				
Number of process lines	One	One	Two	Two
Design tons per hour	62.5	62.5	62.5	100
Design tons per day (16 hours)	1,000	1,000	1,000	1,600
Design tons per year (5,000 hours)	312,500	312,500	312,500	500,000
Normalized capital investment (in thousands):				
Total:				
1974 dollars	$ 5,200	$11,600	$14,000	$15,500
1976 dollars‡	5,980	13,340	16,100	17,830
Total per ton of daily capacity:				
1974 dollars	5.2	11.6	14.0	9.7
1976 dollars‡	5.98	13.34	16.1	11.14
Annualized capital cost:				
@ 10% per year:				
1974 dollars	520	1,160	1,400	1,550
1976 dollars‡	598	1,334	1,610	1,785
@ 25% per year:				
1974 dollars	1,300	2,900	3,500	3,875
1976 dollars‡	1,495	3,335	4,025	4,460
Capital cost per ton of raw waste processed (1974 dollars):				
@ 10% capital charge, and annual capacity utilization at–				
90%	$1.85	$ 4.15	$ 5.00	$ 3.45
75%	2.20	4.95	5.95	4.15
60%	2.75	6.10	7.35	5.15
@ 25% capital charge, and annual capacity utilization at–				
90%	4.60	10.35	12.50	8.60
75%	5.55	12.35	14.90	10.35
60%	6.85	15.25	18.40	12.90

*Office of Solid Waste Management Programs, Resource Recovery Division. Based on original plant design cost estimates by the National Center for Resource Recovery (NCRR), Midwest Research Institute (MRI), the General Electric Co. (GE), and other proprietary sources ("X").

†All plants utilize two-stage shredding and air classification, with magnetic separation of ferrous material and handpicking of paper. Not included: glass and nonferrous recovery options, shredded fuel transport facilities, and land costs.

‡1976 values escalated by 1.15 x 1974 values to account for inflation to midpoint of construction period.

two completely independent process lines, considerably more material storage space (a particularly costly item for these plants), a pit-and-crane material feed system, and nearly twice the fully enclosed building area (exclusive of input and output storage) of the NCRR design. A significant part of the higher cost of plant X is, of course, due to its larger design capacity.

Annualized Capital Cost

Annual capital cost is presented on the basis of two alternative fixed charge (capital recovery) rates: a low 10-percent rate to illustrate the public sector financing option, and a high 25-percent rate to illustrate annual capital cost allocation under a private industry financing option. It should be emphasized that the 25-percent private rate includes a built-in profit return on the equity portion of the original investment. The low 10-percent rate includes only interest and amortization for an investment wholly financed by long-term, tax-free borrowing.

The apparent differences between these two institutional approaches to plant financing are quite substantial–a factor of 2.5 in the amounts. It should be pointed out that part of this difference represents a Federal tax subsidy for local public-sector loans, i.e., the tax-free nature of local government bonds.

Capital Cost Per Ton

Capital cost per ton is shown in Table 32 on the basis of the two alternative fixed charge rates and three alternative capacity-utilization rates. The latter are based on a somewhat arbitrary maximum design capacity utilization of 5,000 hours per year. Ninety-percent capacity utilization probably represents a high design rate from a practical standpoint. The various lower rates can reflect a combination of an intentionally restricted operating schedule (fewer hours per day or days per week), additional equipment downtime for unscheduled repairs, or restricted throughput rates due to low raw waste deliveries or output market bottlenecks.

Other things being equal, unit capital costs will be about 20 percent higher at a 75 percent capacity rate than at a 90 percent rate, and about 25 percent higher still if the plant utilization rate falls to 60 percent. Overall, the difference between achieving only a 60 percent rate as opposed to the 90 percent rate is a capital cost per ton penalty of 50 percent. As shown in Table 32, this penalty varies in absolute dollar terms from a low of just under $1.00 per ton (NCRR/EPA at 10 percent capital charge) up to a high of almost $6.00 per ton for the high-capital-cost GE/EPA plant (under the 25 percent capital charge rate). At the 10 percent charge rate, this factor alone accounts for differences of up to $2.00 or more per ton for the MRI and GE designs. Even the outwardly small differences of 75 versus 90 percent or 60 versus 75 percent capacity utilization result in cost differences of $0.35 to $1.60 per ton for the plants in our sample group. At the higher 25-percent fixed charge rate, the effect of differences in utilization rates is magnified 2.5 times.

COMPARATIVE SUMMARY OF NORMALIZED ESTIMATES FOR OPERATING AND MAINTENANCE COSTS

Table 33 provides a comparison of the operating and maintenance (O and M) cost estimates for the four preliminary designs, adjusted to account for certain design standardizations and revised to reflect 1974 base-year average national labor and utility cost factors. (It should be recalled that O and M costs do not include an item for capital charges, or "capital recovery." Nor do they at this point reflect any adjustments either for dump fees charged to those delivering solid wastes or revenues received from product sales. In other words, they represent only the on-site labor, material, and utility costs of the processing facility.)

Two features of the resulting normalized O and M cost estimates are especially worth noting. The first is the relatively close grouping of the estimates for the different plants. Thus, for a given base year, say 1974, and a given relative operating level (say the 90-percent capacity rate), the unit cost estimates differ by not more than about $1.00 per ton (20 percent). This represents a surprisingly close agreement among the different sources, especially since there is so little real operating experience upon which to base estimates.

The second general conclusion is that if the estimates for the several plant capacity utilization rates are accurate, the unit operating costs are moderately responsive to changes in operating levels. Thus, the O and M cost variation for a given plant over its operating range between 60 and 90 percent of its rated capacity was estimated at about $1.00 per ton (in 1974 dollars) for all four of the plants. However, the engineering data on which the O and M cost penalties for undercapacity utilization are based are quite sketchy. There are no published estimates or analyses of this relationship, but it apparently warrants more attention.

SUMMARY OF TOTAL AND NET COST ESTIMATES

The final synthesis of cost and revenue estimates is presented in two steps. The first step, summarized in Table 34, combines the three categories of costs (capital, O and M, and "other special costs") into a range of total cost estimates for each of the four designs in our sample. The second step combines the total cost and revenue estimates into a set of net cost (or net revenue) results (Table 35).

Total Cost Estimates

In the first part of Table 34, capital costs from Table 32 are combined with basic O and M processing

TABLE 33

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATES FOR FOUR DRY-SHREDDED-FUEL PROCESSING PLANT DESIGNS*

Plant capacity and O and M cost measures	NCRR/EPA	MRI/EPA	GE/EPA	Plant X
Plant capacity factors:				
Number of process lines	One	One	Two	Two
Design tons per hour	62.5	62.5	62.5	100
Design tons per day (16 hours)	1,000	1,000	1,000	1,600
Design tons per year (5,000 hours)	312,500	312,500	312,500	500,000
Total annual O and M costs (in thousands):				
In 1974 dollars, with annual capacity utilization at–				
90%	$ 1,288	$ 1,330	$ 1,554	$ 2,205
75%	1,128	1,175	1,363	1,931
60%	1,045	1,083	1,264	1,740
In 1976 dollars,† with annual capacity utilization at–				
90%	1,540	1,596	1,862	2,655
75%	1,351	1,410	1,533	2,325
60%	1,254	1,302	1,520	2,085
O and M costs per ton of waste processed:				
In 1974 dollars with annual capacity utilization at–				
90%	$ 4.60	$ 4.75	$ 5.55	$ 4.90
75%	4.80	5.00	5.80	5.15
60%	5.50	5.70	6.65	5.80
In 1976 dollars,† with annual capacity utilization at–				
90%	5.50	5.70	6.65	5.90
75%	5.75	6.00	6.95	6.20
60%	6.60	6.85	8.00	6.95

*Office of Solid Waste Management Programs, Resource Recovery Division. Based on original plant design cost estimates by the National Center for Resource Recovery (NCRR), Midwest Research Institute (MRI), General Electric Co. (GE), and other proprietary sources ("X").

†Inflation of 10 percent per year assumed for 2-year escalation factor of 20 percent.

costs from Table 33. The resulting "total processing costs" are unique for each of the four preliminary plant designs. Basic processing costs are estimated to be from $6.45 per ton for NCRR/EPA to $10.55 for GE/EPA at the low 10-percent capital charge and the high 90-percent utilization rate. At the other extreme (high capital charge and low utilization rate), these basic costs are 90 to 150 percent higher, depending on design, and range from $9.20 to $25.05.

Total process cost differences among the four plants represent differences within the engineering design community as to the capital and operating resource requirements to process mixed waste at the indicated scales. These are differences remaining after our recalculations to standardize design and costing parameters. Considering the state of technological development, the differences in process cost estimates among the four designs are less than might have been expected. In fact, the differences among plants by different designers are less than the differences for any given plant due to alternative capital charge and operating rate assumptions.

As previously discussed, the "other special cost" items may or may not be relevant under particular locational and institutional circumstances. Thus, each of these cost items may have zero values for particular cases, or they each may add substantial annual and per ton expense to the recovery operation. The values included in Table 34 are our EPA "high" cost estimates. They do not necessarily reflect

TABLE 34

SUMMARY OF NORMALIZED COST ESTIMATES FOR FOUR DRY-SHREDDED-FUEL PROCESSING PLANT DESIGNS*

(Per ton of raw waste input, 1974 cost base)

Cost categories	NCRR/EPA Capacity utilization		MRI/EPA Capacity utilization		GE/EPA Capacity utilization		"X"/EPA Capacity utilization	
	90%	60%	90%	60%	90%	60%	90%	60%
Public sector finance option								
@ 10% annual capital charge:								
Capital cost	$1.85	$2.75	$4.15	$6.10	$5.00	$7.35	$3.45	$9.15
O and M cost	4.60	5.50	4.75	5.70	5.55	6.65	4.90	5.80
Subtotal process cost	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Total other possible special costs†	5.15	5.65	6.05	7.00	6.40	7.50	5.65	6.40
Total cost per ton	11.60	13.90	14.95	18.80	16.95	21.50	14.00	17.35
Private sector finance option								
@ 25% annual capital charge:								
Capital cost	4.60	6.85	10.35	15.25	12.50	18.40	8.60	12.90
O and M cost	4.60	5.50	4.75	5.70	5.55	6.65	4.90	5.80
Subtotal process cost	9.20	12.35	15.10	20.95	18.05	25.05	13.50	18.70
Total other possible special costs†	5.15	5.65	6.05	7.00	6.40	7.50	5.65	6.40
Total cost per ton	14.35	18.00	21.15	27.95	24.45	32.55	19.15	25.10

*Office of Solid Waste Management Programs, Resource Recovery Division. Based on original plant design cost estimates by the National Center for Resource Recovery (NCRR), Midwest Research Institute (MRI), the General Electric Co. (GE), and other proprietary sources ("X").

†Sum of "high" estimated values for all five of the following "other possible costs," including: (1) property taxes at 4.0% of total investment; (2) land and unusual site work of $1.6 million at 7.0% per year interest; (3) residual waste disposal at $5.00 per ton of waste ($1.00 per raw input ton); (4) shredded fuel transport at $3.00 per ton ($2.00 per raw input ton); and (5) nonplant overhead charges of $1.00 per ton of raw waste processed.

either the particular values or, in some cases, even the same categories of costs estimated in the original design source documents. Rather, they have been applied to all the designs in our sample as an added means of normalizing the estimates for comparative purposes.

Thus, the "other special cost" elements, taken as a group, can add up to any value from zero to some significant cost. The *maximum* value for our comparative cases varies between $5.15 and $7.50 per ton, depending on plant capital cost (a variable in the property tax cost function) and level of capacity utilization. In the very special case where "other special costs" are all zero, then total processing cost is the only cost to be balanced against product revenues to determine the net cost or revenue from plant operation.

Net Revenue or Cost Results

The final step in the cost-estimating procedure combines total product revenues with total costs to yield net revenue (profit) or cost (dump fee). Table 35 presents four sets of net cost calculations for each of the four case study designs to show the various combinations of: high revenue with low cost; high revenue with high cost; low revenue with low cost; and low revenue with high cost.

The first two net revenue calculations for each plant represent the low and the high cost possibilities as developed in Table 34 in conjunction with the "high" ($15.85 per ton) total revenue estimate from Table 31. The first net revenue line (for Case 1) indicates positive net revenues for all plants. Thus, so long as "high" revenues can be combined with costs that do not exceed standard process cost by substantial amounts, all four plants appear profitable at the current estimated value for Case 1 conditions. Even when a maximum "other special cost" sum (see Case 2, Table 35) is charged, NCRR/EPA remains profitable even at the 60-percent capacity utilization rate, and both MRI/EPA and Plant X continue to show net revenue at high utilization rates.

TABLE 35

SUMMARY OF ALTERNATIVE NET REVENUE (COST) CALCULATIONS FOR FOUR PRELIMINARY PLANT DESIGNS AT TWO ALTERNATIVE CAPACITY UTILIZATION RATES*

(Per ton of raw waste input, 1974 cost base)

	NCRR/EPA Capacity utilization		MRI/EPA Capacity utilization		GE/EPA Capacity utilization		"X"/EPA Capacity utilization	
	90%	60%	90%	60%	90%	60%	90%	60%
High-revenue cases:								
Case 1: High-revenue estimate with process cost only								
Total product revenue	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85
Less: total process cost†	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Less: min. other special costs	–	–	–	–	–	–	–	–
Equals: net revenue	$ 9.40	$ 7.60	$ 6.95	$ 4.05	$ 5.30	$ 1.85	$ 7.50	$ 4.90
Case 2: High-revenue estimate with maximum other special costs								
Total product revenue	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85	$15.85
Less: total process cost†	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Less: max. other special costs	5.15	5.65	6.05	7.00	6.40	7.50	5.65	6.40
Equals: net revenue (cost)	$ 4.25	$ 1.95	$ 0.90	($ 2.95)	($ 1.10)	($ 5.65)	$ 1.85	($ 1.50)
Low-revenue cases:								
Case 3: Low-revenue estimate with process cost only								
Total product revenue	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40
Less: total process cost†	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Less: min. other special costs	–	–	–	–	–	–	–	–
Equals: net revenue (cost)	($ 3.05)	($ 4.85)	($ 5.50)	($ 8.40)	($ 7.15)	($10.60)	($ 4.95)	($ 7.55)
Case 4: Low-revenue estimate with maximum other special costs								
Total product revenue	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40	$ 3.40
Less: total process cost†	6.45	8.25	8.90	11.80	10.55	14.00	8.35	10.95
Less: max. other special costs	5.15	5.65	6.05	7.00	6.40	7.50	5.65	6.40
Equals: net revenue (cost)	($ 8.20)	($10.50)	($11.55)	($15.40)	($13.55)	($18.10)	($10.60)	($13.95)

*Office of Solid Waste Management Programs, Resource Recovery Division. Based on original plant design cost estimates by the National Center for Resource Recovery (NCRR), Midwest Research Institute (MRI), General Electric Co. (GE), and other proprietary sources ("X").

†Sum of capital cost and O and M cost from Table 34. Capital cost based on 10-percent annual fixed-charge rate (capital recovery).

For the low-revenue ($3.40 per ton) Cases 3 and 4, net revenue disappears, even where low costs are involved. Results for Case 3 show net costs of about $3.00 to $7.00 per ton at 90-percent utilization rates and $5.00 to $11.00 at low capacity rates. It is noteworthy that the net costs in this line are still generally competitive with landfill costs in many, if not most, highly urbanized areas.

The final "bottom line" (Case 4 of Table 35) represents the worst situation with respect to resource recovery—i.e., low revenue combined with highest possible cost for the plant cases presented. Even the results for this worst-case resource recovery alternative are encouraging, however, because net cost estimates for all plants remain competitive with conventional incineration.

A number of caveats must be made. The first is that the results in Table 35 all assume the low (public sector) 10-percent capital recovery rate. Costs increase under a strict private-enterprise rate of return formulation. However, a privately financed facility, if well managed and strategically located, could be profitable under some realistic locational and market circumstances. Another point that must be kept in mind is that all the basic cost estimates are themselves subject to substantial possibilities for error. No such plant has yet been constructed or operated, and all costs are based on preliminary design estimates rather than final detailed design figures. Further, a serious effort has been made to present costs on a national average basis, and many of our urban areas will have costs at least 10 to 15 percent higher than these estimates on the basis of location alone.

Finally, it should be noted that the present analysis does not evaluate the question of "economies of scale" for plants of different design capacities. Generally one would expect that, other things being equal, plants smaller than those in the study sample would show higher capital and operating costs per ton than the estimates presented here. Conversely, larger plants might result in somewhat lower unit costs. However, an analysis of the economies of scale is beyond the scope of this study.

SUMMARY AND CONCLUSIONS

The Environmental Protection Agency has analyzed a number of engineering design conceptions for the next generation of shredded-fuel recovery plants based on the St. Louis prototype. Existing cost estimates prepared by engineering consultant and system development companies are not directly comparable with one another because of differences in estimating methods, accounting formats, and location-specific costing factors. Therefore five recent preliminary design cost studies were normalized to produce comparable cost estimates representative of the degree of consensus within the engineering community.

The results indicate the differences in cost estimates among design conceptions and engineering firms are still quite significant, even after adjustments for location, time, and other nonstandard elements of costing procedure. However, the differences are no greater than might be expected given the present state of technological development and lack of operating commercial prototypes. Indeed, differences in basic capital and operating costs attributable to different technical engineering conceptions are in many respects of less consequence than the differences introduced by the use of alternative costing methods and location-specific cost factors.

Analysis of normalized cost estimates and alternative product selling-price projections indicates that potential net cost projections will fall in a very broad range from positive to negative. The results suggest that there could be some favorable cases where operation of this type of processing plant will yield a profit from sales of product, exclusive of dump fees. Intermediate cases—i.e., those which combine either high revenue with high cost or low revenue with low cost—generally appear competitive with current or projected landfill costs in many if not most U.S. cities. All cases using low-cost (public sector) financing options, including even the highest cost case-study plant, were at least competitive with conventional municipal incineration.

From a project planning and evaluation standpoint, three conclusions of the analysis merit special emphasis:

1. *The relative importance of total revenue, and the very large absolute differences between high and low estimates of revenue.* The most significant aspects of uncertainty relate to the potential market value of the largest volume product, the shredded fuel. Differences between "high" and "low" shredded-fuel

selling price estimates account for most of the difference between a $16.00 and a $3.00 total product revenue per ton of raw waste processed. This price difference dwarfs almost all other elements of the net cost and revenue estimates.

2. *The significance of maintaining reasonably high capacity utilization rates.* This is evident in the comparisons for individual plants where differences in net cost of $2.00 to over $4.00 per ton consistently result for estimates at the 90 percent versus 60 percent capacity utilization rates. The high cost of failure to maintain high capacity utilization levels underlines the importance of sound planning and high quality management.

3. *The cumulative importance of "other special cost" elements.* If costs are divided into three categories as in Table 34, it comes as something of a surprise that "other costs" can be larger in total than either the standard capital cost or the operating-and-maintenance processing cost categories. The potential cumulative effect of these items on the overall net cost picture suggests that they are worthy of considerable attention by planners and designers.

REFERENCES

1. Smith, F. A. An evaluation of the cost of recovering dry-shredded fuel and material resources from mixed community solid waste. Washington, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Resource Recovery Division, Aug. 20, 1974. various pagings. (Unpublished report.)
2. Materials recovery system; engineering feasibility study. Washington, National Center for Resource Recovery, Inc., Dec. 1972. various pagings.
3. Cost analysis for the New Orleans resource recovery and disposal program, Washington, National Center for Resource Recovery, Inc., 1974. 108 p.
4. Franklin, W. E., et al. Resource recovery processes for mixed municipal solid wastes; part I—technical review and economic analysis. [Environmental Protection Publication SW-101.] [Cincinnati], U.S. Environmental Protection Agency, 1973. 67 p.
5. Godfrey, D. E., et al. [General Electric Company.] Preliminary design of a solid waste separation plant; final report. Hartford, Conn., State of Connecticut Department of Environmental Protection, July 1973. 208 p.

Chapter 6

STATUS OF WASTE REDUCTION EFFORTS AND IMPLEMENTATION OF RESOURCE RECOVERY SYSTEMS

The foregoing chapters presented technical descriptions of waste reduction measures and resource recovery systems. This chapter discusses the status of waste reduction efforts by private industry, States, and localities, and the status of resource recovery system implementation and the issues that affect the rate of implementation.

WASTE REDUCTION EFFORTS

The emergence of waste reduction as an issue of significance in both resource and waste management planning has been aided by two concurrent but unrelated forces: the growth and widespread acceptance of the environmental ethic proclaimed on Earth Day 1970, and the energy and material shortages that became apparent in late 1972. These forces have resulted in some important achievements during the past several years. A number of legislative actions have been taken at both the State and local level to achieve waste reduction, and representatives of several major governmental and public interest organizations have called for waste reduction actions as a major approach to solving our nation's resource conservation and waste management problems. Additionally, many industries have either reduced the variety of products they manufacture or redesigned their products to conserve the resources that are in short supply. More universal adoption of the waste reduction ethic nevertheless has been hampered both by a lack of information on methods for accomplishing waste reduction and by the long-established habit of viewing resources as readily available and inexpensive.

Industry Efforts

Perhaps no development has caught industry more off guard than the epidemic of resource shortages and resultant price rises on basic commodities that struck the United States economy in late 1972 and 1973 and continues through to the present. By mid-1973, shortages had been reported for such basic materials as paper, steel, plastics, aluminum, and crude oil. Since 1972, price increases of between 30 and 40 percent have been reported for aluminum, steel, and petrochemicals. Crude oil prices alone have risen by over 100 percent since the beginning of 1972.

These shortages can be attributed to a number of factors, including the quantity of materials exploitable at current technology and price levels, lack of capacity in the materials processing industries, and continued pressure resulting from increasing material and product demand. The critical question that arises is whether these shortages will continue throughout the decade. If the world economy remains sluggish, capacity shortages may well be significantly reduced and prices could level off. On the other hand, shortages and spiraling prices could reappear as soon as economic growth accelerates.

It is a combination of uncertainty coupled with current resource shortages and price levels that have caused many industries to reconsider their product designs and selections. Some of the changes have begun to occur already. Product lines are being pruned and consolidated as more and more companies discard products with lower profit margins. The Aluminum Company of America, for example, recently announced that it will no longer manufacture aluminum foil, despite the fact that it previously produced an estimated 20 percent of the $200 million market. Similarly, the foods division of Castle & Cooke, Inc., has reduced its number of fruit cuts and can sizes from 27 retail items to only 11 in just two can sizes, 20-ounce and 8-ounce.

The inflation of costs is a major factor in forcing a corporate shift in emphasis away from volume growth and toward profit growth. In the 1960's and early 1970's, when production costs were relatively stable, greater volume meant more profit as soon as fixed costs were covered. However, this has changed as nearly all production costs continue to rise and profit margins shrink. The result is that many manufacturers are now discarding high-volume, low-margin products in favor of those items with higher margins and lower volumes. Thus increased costs are already tending to force industry to implement waste reduction practices.

As many companies have begun to pare down their product lines, others have chosen to look carefully at individual product designs in hopes of redesigning them to use fewer resources. Thus, the Campbell Soup Company has designed and begun to market a new tinplated drawn-and-ironed can with a tin-free steel end for its dog food line. It is estimated that this can uses 30 percent less material, which results directly in cost savings. As of September 1974, a conventional three-piece, soldered-seam tinplate can cost approximately $31.70 per thousand, while the drawn-and-ironed can cost $23.25 per thousand, a savings of approximately 36 percent.

There are many other redesign efforts being made to conserve resources and cut rising costs. The St. Regis Paper Company, for example, has noted that obtaining more product from less material is now a mandate because of paperboard shortages and mounting costs. Thus the company has suggested many new package designs to reduce board use, including the replacement of top-loading with end-loading containers, the increased use of single-die-cut containers instead of containers with multiple interior components, and the standardization of container sizes.

It is expected that industry will continue to redesign products if shortages and price increases continue. It is significant that these product design shifts are now becoming a requirement among product designers and marketers; that is, resource use is now a high-priority consideration in the manufacture of a product. Once this direction is firmly established, the impacts upon resource use, environmental pollution, and waste generation can only be positive.

Present Activity by States and Localities

Packaging control legislation has been introduced in 50 State legislatures and numerous county and city councils since 1971. As of October 1974, three States (Oregon, Vermont, and South Dakota) had passed laws relating strictly to beer and soft drink containers, and one State (Minnesota) had passed a law that affects all major littered items. Legislation affecting beverage containers has also been passed at the local level—for example, in Oberlin, Ohio, Loudoun County, Virginia, and Bowie, Maryland, although in the latter two localities the laws have not been implemented due to legal challenges. A brief discussion of the major pieces of State legislation follows:

Oregon. A mandatory deposit law has been in effect in Oregon since October 1, 1972. The legislation requires a minimum 2-cent refund to purchasers on the return of "certified" containers of beer, malt beverages, and carbonated soft drinks, and a 5-cent refund on the return of all other containers for those beverages. Certified containers are defined as those used by, and accepted for reuse by, more than one manufacturer. In addition, the law outlaws the sale of flip-top or pull-tab beverage containers.

A preliminary review of the effects of the Oregon law is contained in the *Second Report to Congress.* Since that time, a comprehensive report on the law and its results has been released in draft form by the State of Oregon. That report indicates that (1) beverage container litter has been decreased by an estimated 66 percent, (2) nonrefillable containers have declined to 12 percent of the soft drink market and 6 percent of the beer market, (3) sales of beer and soft drinks have neither declined below the level of the year prior to enactment nor increased as in previous years, (4) the price of beer and soft drinks to the consumer has been lowered on the average, (5) refillable soft drink containers are being returned at a rate of 96 percent and refillable beer containers at a rate of 85 percent, (6) the law has decreased container manufacturing and canning industry profits substantially due to the transition from nonreturnable to returnable containers, (7) significant job losses have occurred in the container manufacturing and canning industries, and (8) significant numbers of jobs have been created in the brewing, soft drink, and retail sectors of the economy.

Vermont. A mandatory law has been in effect in Vermont since September 1, 1973. The legislation requires a deposit and refund of a minimum of

5 cents on the purchase and return of all containers for beer, malt beverages, and carbonated soft drinks. The law also requires that a handling charge equivalent to 20 percent of the deposit be paid by the distributor to the retailer.

This law has not been in force long enough to allow an evaluation of its effectiveness. However, preliminary reports suggest a reduction in beverage container litter, a sales decline for both beer and soft drinks, an increase in employment (primarily in the product distribution and retail industries), and a heavy burden on retailers, particularly those located close to the border with New Hampshire, which does not require a deposit on beverage containers.

South Dakota. In February 1974, the South Dakota Legislature passed a law prohibiting the use of beverage containers that are not "reusable" or "biodegradable." Definitions for these terms will be provided by the State Secretary of Commerce. The law becomes effective July 1, 1976.

Minnesota. In May 1973, the State of Minnesota enacted a law designed to reduce the amount and change the characteristics of its solid wastes. The legislation applies specifically to packaging wastes. It grants the State Pollution Control Agency the authority to prohibit the introduction of new package designs into the Minnesota market. Despite considerable difficulty, guidelines under which the agency shall operate under this law were adopted by the State Pollution Control Board in October 1974. No actions have yet been taken under these newly adopted regulations.

Washington. Legislation was passed in Washington in May 1971, placing an annual assessment upon manufacturers, wholesalers, and retailers of products found in litter, including containers and packaging, newspapers and magazines, and food and beverages. The rate of the special tax is $0.00015 per dollar of sales made within the State. Funds collected under the statute are used for public education on the subject of littering, studies of the effect of the legislation on littering behavior, and the placement of litter receptacles in all public places.

Support of Public Interest Organizations

Perhaps the strongest support for the implementation of waste reduction policies has come from citizens groups and spokesmen for the public interest. Basing their appeal upon both resource conservation and solid waste management needs, these groups have consistently called for a national effort to decrease the quantity of wastes generated.

The National League of Cities and U.S. Conference of Mayors, for example, have urged a strong Federal role in waste reduction. Claiming that the private sector alone cannot restrict excessive waste generation, these two groups have called for the adoption of regulatory measures directed at products that result in excessive solid waste and increased disposal problems. Similarly, an environmental spokesman has noted that "We can no longer afford to ignore the broader implications of the solid waste disposal crisis facing cities across the country. It is a crisis of raw materials and energy management and policy-making that will affect the country for years to come."

The efforts of such groups have been hampered by a lack of specific information on the types of mechanisms most applicable to waste reduction. The only specific waste reduction measure supported by a large number of public organizations, including the National League of Cities, the National Association of Counties, the League of Women Voters, and all the major environmental organizations, is a mandatory deposit mechanism for all beer and soft drink containers. Support for the mechanism by public interest groups has been very vocal, and they have testified in favor of legislation to establish mandatory deposits at local, State, and Federal hearings.

IMPLEMENTATION OF RESOURCE RECOVERY SYSTEMS

One important factor in the implementation of resource recovery systems, plant cost, was discussed in the preceding chapter. Other important factors, including environmental impact, technological risks, market risks, legal constraints, availability of information, and availability of financing, are discussed in this section; a summary of activities in selected States and communities is also presented.

Environmental Impact of Resource Recovery Facilities

The environmental impact of resource recovery facilities will vary with the different types of systems. The systems can be analyzed in two parts: (a) feedstock preparation, including materials recovery, and (b) energy conversion. Feedstock preparation refers to the handling (receiving, conveying, and storage) and processing (shredding, pulping, and classification) for recovery of materials and preparation of the waste for energy conversion. Energy conversion is the chemical process (combustion, pyrolysis, or biodecomposition) that converts the waste into energy.

Feedstock Preparation and Materials Recovery. Feedstock preparation includes receiving, size reduction (shredding or pulping), classification, and storage facilities. Potential emissions to the air, water, and land, including noise and odor, are like those of other light industry and can be controlled by relatively simple techniques. The most significant emissions are: dust emitted to the air from cyclone separators, waterborne contaminants resulting from wash-down of waste-handling areas, noise from delivery truck traffic and from processing equipment, and odors. The dust can be controlled by dust collectors, the waterborne contaminants by filtration and discharge to sanitary sewers, the noise by selective routing of trucks and enclosures for equipment, and the odors by means of enclosures for all areas in which wastes are handled.

Energy Conversion. There are four predominant types of energy conversion units:

Waterwall Incinerators. Federal standards of performance for new stationary sources (SPNSS) have been promulgated to control emissions from incinerators. All incinerators built after 1971 must comply with SPNSS. Federal water pollution control standards also apply to the potential pollution associated with water used for cooling bottom ash and for operating air pollution control devices (scrubbers).

Powerplant Boilers. SPNSS have not been developed for firing solid waste in combination with fossil fuels in utility or industrial powerplant boilers. SPNSS specifically indicate that retrofitting an existing boiler (defined by SPNSS as a boiler in service or under construction in 1971) to fire solid waste does *not* constitute a "modification" which would require a boiler to comply with SPNSS. Therefore, retrofitted existing boilers shall continue to be under the authority of State and local ambient air quality standards.

Air emission tests have been conducted at only one location: the Union Electric Company's Meramec Plant, where solid waste is burned with coal as part of an energy recovery demonstration supported by an EPA grant to the city of St. Louis. A summary of the results of those tests is presented in the Appendix.

There is a potential for water pollution from settling ponds that receive ash removed by water (sluiced) from the bottom of the furnace. Analysis of settling pond effluents has not been completed.

Pyrolysis Reactors. Pyrolysis reactors were developed to convert waste to energy using little or no ambient (excess) air, thus minimizing or eliminating discharge of gases to the environment. Tests of pilot-scale systems indicate that SPNSS can be met, and all full-scale systems will be required to meet SPNSS for incinerators.

Anaerobic Digestors. Anaerobic digestors have not been developed to a scale sufficient for testing the potential air and water emissions. Based upon laboratory experience, however, air emissions appear to be negligible and water emissions appear to be controllable.

Constraints to Energy Recovery System Implementation

The systems discussed in Chapters 3, 4, and 5 are being evaluated for possible implementation by many communities across the country. The experiences of communities in implementing resource recovery systems indicate that there are a number of constraints, some of which are discussed below.

Technical and Market Risks. Resource recovery technologies and economics have not been completely demonstrated and evaluated, although systems are currently being marketed and constructed. Some technologies have been projected to operate at an economically attractive cost relative to other solid waste management alternatives. Since most systems have not yet been operated on a full-scale, however, there is some uncertainty about their long-term technical and economic feasibility. This uncertainty results in difficult negotiations over the sharing of risks among the parties concerned. The two major types of risks are technical and marketing risks.

Technical Risks. Technical risks include costs and system operating performance, i.e., the ability of the system to perform as designed at the estimated cost. These uncertainties can be reduced only through operation of the system at full scale on a continuous basis.

Marketing Risks. The economic success of a recovery system depends on continuing revenues from product sales. If the product cannot be sold or can be sold only at a discount, the projected net cost will not be realized. This could jeopardize a system's ability to meet bond payments.

Long-term market commitments must therefore be sought from the purchasers of recovered energy and materials. These commitments are difficult to secure because potential buyers have had little experience with products recovered from mixed municipal waste. Frequently buyers will stipulate a trial period before signing a long-term contract. Thus "chicken-and-egg" situations develop: A system cannot be constructed until bonds are sold. Bonds cannot be sold unless long-term market commitments are signed with buyers of recovered products. Buyers will not sign long-term market commitments until the system has actually operated and produced over a trial period.

Marketing risks and barriers are not altogether related to the quality of recovered products; some may be more institutional than technical in nature. For example, utilities may be reluctant to purchase shredded waste for use as a fuel because of the industry's traditional use of fossil fuels, their regulated economic structure, or uncertainties as to future air pollution standards for burning of solid waste as a fuel.

In summary, risk related to technical, economic, and market uncertainties is by itself a sufficiently strong force to impede or delay many future implementations, especially because procurements are determined by public works departments that typically have not dealt before with similar risks. Risk will be reduced when more full-scale systems become operational and the information from these systems is made available.

Inadequate Information and Planning. Inadequate information is an impediment to any decision-making process, but it may be a special hindrance in resource recovery implementation because of the rather complex technological, economic, and marketing considerations. Lack of information impacts at the critical phases of planning, system selection, procurement, and financing. Although comprehensive information based on actual operations is not yet available on the different recovery systems, decision-makers considering resource recovery as a solid waste disposal option can and should be aware of the range, general applicability, and stage of development of the technical alternatives that are being demonstrated today.

The selection of an appropriate resource recovery system for a specific locality is a complicated endeavor involving analyses of marketing, management, financial, technical, and legal issues. The failure of municipalities to recognize the importance of the planning process, hire appropriate consultants to guide them, and carry out the planning properly has slowed or impeded system implementation.

Legal Constraints. There are a variety of State laws that could delay or jeopardize the future implementation of resource recovery systems. Three specific types are particularly important:

Laws Restricting Contract Length. Cities often are prohibited from signing long-term contracts for (a) the purchase of a service or (b) the sale of a product. Laws outlawing such contracts effectively preclude a city from entering into a turnkey contract or a full-service agreement by which a corporation offers to build, operate, and manage a resource recovery system for the life of the facility.

Laws Requiring "Split-Bidding." In split-bidding of construction work, the wiring, the plumbing, the bricks and mortar, etc., are bid for separately. This complicates the procurement of proprietary systems.

Competitive Bidding Laws. "Lowest responsible bidder" laws require that procurements be awarded on a cost basis. Awarding contracts on a cost basis alone makes it difficult for a city to compare other important relative measures such as a firm's financial capability and its technical, marketing, and operating experience.

"Lowest responsible bidder" and other procurement laws were instituted for public-sector purchase of risk-free, off-the-shelf technology. They do not work particularly well when applied to the procurement of a somewhat risky resource recovery system because such a purchase, by its nature, almost requires a negotiating period before final signing of the contract. During the negotiation period, risk apportionment (between public and private sector) and specifications for the products and waste processing can be determined. Unfortunately, reallocation of risk alters costs. Competitive bidding requirements usually make negotiations and revisions of cost illegal.

Although some laws may act as impediments, they usually are not absolute barriers to system implementation. In many cases where laws would adversely affect contract finalizations, cities may petition States for changes in laws or exceptions to the laws.

Availability of Financing

There are two basic sources of capital to finance resource recovery plants: equity financing and debt financing. Thus far, the economic return on investments in resource recovery plants has been too low to attract equity capital. Therefore, most of the focus in plant financing has been on bond market sources of funds: general obligation (GO) bonds of State and local governments, municipal or industrial revenue bonds, and corporate bonds (Table 36).

In times of relative capital shortages, debt financing for recovery plants is very difficult to obtain unless the debt is viewed by investors as "secure," i.e., backed by a municipality (GO bonds) or by a corporation with large financial assets.

Also, the capital markets, especially the debt "track record" must be developed before extensive solid-waste-related industries. Information and a "track record" must be developed before extensive revenue bond financing of resource recovery systems will be available.

Corporate Bond Financing. Recent studies and selected examples suggest that resource recovery plant financing through corporate bonds may be difficult to obtain. Numerous public and private authorities project capital to be in short supply for the next 10 years. For example, the New York Stock Exchange estimated that by 1985 cumulative demands for capital expenditures in the private sector would be $4.7 trillion, while cumulative capital supply would total $4.05 trillion. This indicates a $650 billion cumulative shortfall over that period.

When capital is scarce, projects or corporations that have less than Aa or A bond ratings will have a progressively more difficult time in raising substantial amounts of money in the market. For example, in 1974 (a tight money period), Baa corporations, corporations that have been rated relatively "risky" by the bond-rating agencies, were not able to float any bonds over $50 million, according to a leading investment banking firm. These "risky" corporations, including such firms as Jones and Laughlin, White Motors, Western Union, and Western Pacific Railroad, are better established and have better bond ratings than all but a few firms currently marketing resource recovery systems.

TABLE 36

BOND FINANCING OPTIONS FOR RESOURCE RECOVERY PLANTS

Type	Issuer	Security
Corporate bond	Private company	Faith and credit of the company
General obligation bond	State or local government	Faith and credit of the government entity
Municipal revenue bond	State or local government or special authority	Project revenues
Industrial revenue bond (Pollution control revenue bond)	State or local government	Faith and credit of the corporation*

*Traditionally these bonds have financed pollution control facilities that in reality have no revenue stream. The "revenue" aspect of the bond is the periodic payment from the corporation to the city to retire the obligation. Legally the corporation is responsible to the bondholder. However, with both these bonds and municipal revenue bonds, a contractual agreement may be drawn up in which the municipality pledges an unconditional "put or pay," i.e., agreement to pay a set amount whether waste is delivered or not, and also to escalate dump fees in the event of reduced plant output sales or cost increases. If a city will "put or pay," these bonds are viewed essentially as general obligation bonds.

General Obligation Bond Financing. Though several indicators point to possible shortages of private capital over the next 10 years, the funding of resource recovery plants through municipal general obligation bonds remains a possibility. There does not appear to be any significant prospect of a major shortage of funds for GO bond markets at State or local levels. Thus, public agencies that are willing to extend their general obligation debt for these purposes should not have difficulty in obtaining capital. Decisions of municipal officials on GO bond financing of recovery plants are dependent on several questions. One is simply whether the city is willing to assume the full capital responsibility and associated risk for a plant. Some municipalities have been willing to assume this risk, while others have been reluctant.

The Municipal Financial Officers Association reports that most cities are not near their statutory debt ceiling; thus, this factor should not constrain municipal GO bond financing. However, financing of a recovery plant with GO bonds would generally require voter approval and might require an increase in taxes, a politically unpopular action.

The potential impact on the overall general obligation bond markets of increased municipal recovery plant financing can be predicted. The Federal Reserve predicts a total outstanding State and local debt obligation in 1980 of $370 billion and in 1985 of $548 billion, up from $189 billion in 1973. This is the predicted level of State and local funding considering both demand and supply of capital. Assuming that 30 municipally financed plants costing an average of $50 million each are constructed by 1980, capital requirements would total only $1.5 billion, a negligible fraction of total outstanding debt by 1985. On a yearly basis, the Federal Reserve prediction suggests an increase annually of about $25 billion in outstanding debt (net increase taking into account new obligations and retirements). Even if as many as 15 plants were financed in a single year (an unlikely occurrence), the recovery plant financing would constitute only 3 percent of the increase in State and local debt in that year. Thus, it appears unlikely that general obligation bond financing of recovery plants would have any significant impact on municipal bond markets in the aggregate.

Revenue Bond Financing. Revenue bonds are similar to general obligation bonds except that they are guaranteed by the revenues of a project, not by the full faith and credit of a State or local government. Because resource recovery technology is relatively unproven and realization of projected revenues is uncertain, revenue bonds are somewhat more difficult to sell, unless they are backed by the full faith and credit of a public or private corporation. However, if private, the corporation must be large and well financed to attract potential bond purchasers, who are not willing to take risks on new technology with small corporations. In the case of a public corporation, a city or State must agree to guarantee the bonds in order to reduce the bondholders' risk in financing a new technology.

Availability of State Financing. A final factor that can influence recovery plant financing is State programs for such financing. The funding levels of many of these programs are small relative to resource recovery plant costs. To date only one State, New York, has grant funds sufficient to influence plant financing significantly, and only one State, Connecticut, has a large bond authorization.

Summary. It appears that financing of recovery plants through corporate bonds or revenue bonds over the next 5 or 10 years could be difficult. However, general obligation bond financing should be possible. Pollution control revenue bond financing should be available if backed by a major corporation or if tied (by contract) to a guaranteed coverage of plant costs by cities. States will provide some financing but the amount is unclear. Thus, there is evidence to indicate that there is not, nor will there be, a major capital availability problem for resource recovery systems.

Present Activities in States and Cities

Developments in technology combined with environmental and economic pressures described earlier continue to encourage initiatives at the State and local levels.[1]

State Activities. As of March 1975, 10 States had grant or loan programs for the construction of resource recovery systems (Table 37); 12 States were involved in planning or regulating resource recovery activities on a statewide basis; and five States had the authority to create agencies to operate resource recovery facilities. In this last group, the Connecticut Resources Recovery Authority is the only such

TABLE 37

SUMMARY OF STATE INITIATIVES IN RESOURCE RECOVERY, MARCH 1975

States with grant or loan programs	States involved in planning or regulation	States with operating authority
California	California	Connecticut
Florida	Connecticut	Florida
Illinois	Florida	Michigan
Maryland	Hawaii	Rhode Island
Michigan	Massachusetts	Wisconsin
Minnesota	Michigan	
New York	Minnesota	
Pennsylvania	New York	
Tennessee	Pennsylvania	
Washington	Rhode Island	
	Vermont	
	Wisconsin	

agency that has been funded and has committed funds to construction. A summary of activities in selected States follows:

California. In 1972, the California Legislature enacted the Solid Waste Management and Resource Recovery Act. The Act established a Solid Waste Management Board, required all counties to adopt solid waste management plans to be approved by the State board, placed priority upon resource recovery, and mandated the Solid Waste Management Board to develop a State resource recovery plan. A draft has been completed and is being circulated for public review.

Connecticut. As a result of a comprehensive State plan developed by the Connecticut Department of Environmental Protection, the State legislature created the Connecticut Resources Recovery Authority (CRRA). The Authority is implementing the plan, which calls for the construction of 10 resource recovery facilities by 1985 that will process 84 percent of the State's waste. CRRA has been given $250 million bonding authority for facility construction. During formulation of the plan, the U.S. Environmental Protection Agency funded a study which gave the State an independent commentary of the proposed legislation, provided a framework for evaluation of proposed projects, made management and organization recommendations, and recommended financing mechanisms. Garrett Research and Development Company has been selected to build the first plant in Bridgeport, and Combustion Equipment Associates, Inc., has been selected to build the second plant in New Britain to serve the Greater Hartford area.

Florida. In mid-1974, Florida enacted legislation creating a Resource Recovery and Management Advisory Council and mandating a State resource recovery program. The Council is currently developing the plan.

Hawaii. In 1971, the Hawaii Legislature enacted legislation calling for the development of a Hawaii State Plan for Solid Waste Recycling. This plan, completed in 1973, is currently being implemented. The State has set aside land in the harbor area of Honolulu as a centralized park and has invested in the design of a plant to convert organic wastes to oil. A pilot plant is expected to be constructed sometime in 1976.

Illinois. The State Division of Land Pollution Control is initiating a $3 million grant program for solid waste management planning and resource recovery demonstrations.

Massachusetts. The Commonwealth of Massachusetts is implementing a resource recovery plan. Proposals have been requested for a plant in the Greater Lawrence area, the first implementation region. The plan features a system of privately financed, privately operated, State-controlled resource recovery plants.

Maryland. The Maryland Environmental Service (MES), a State agency responsible for sewage and solid waste management, is authorized to provide grants or loans for resource recovery facilities. In 1972, MES loaned $4 million to the city of

Baltimore to construct the $16 million EPA-supported resource recovery demonstration plant.

Michigan. Late in 1974, the State enacted legislation to develop a State resource recovery plan by 1978 and to authorize the State to construct and operate facilities, to contract for services, to issue revenue bonds, and to make loans to local governments.

Minnesota. A $3.5 million solid waste disposal and resource recovery grant program, which was authorized by the State legislature in 1973, is being implemented by the Minnesota Pollution Control Authority. Grants totaling approximately $800,000 have been made to support solid waste planning and resource recovery feasibility studies.

New York. In 1972, New York State voters approved a $1.1 billion Environmental Bond, which included $175 million for solid waste disposal and resource recovery facilities. The regulations provide for State funding of up to 25 percent of the cost of solid waste disposal projects and up to 50 percent of the cost of resource recovery projects. To date, $116 million has been appropriated for 17 resource recovery projects. Funds will be released to each grantee upon completion of contractor selection and system design.

Pennsylvania. In 1974, the Pennsylvania Legislature enacted the Pennsylvania Solid Waste Resource Recovery Development Act, creating a State loan program for local resource recovery projects. Rules and regulations for the program are now being drafted. The program will make $20 million in loans available for design and construction of resource recovery facilities.

Rhode Island. In 1974, the Rhode Island Legislature created the Rhode Island Solid Waste Recovery Management Corporation. The legislation that created the corporation is the result of the State Solid Waste Management Plan and is modeled after the Connecticut resource recovery legislation. The U.S. Environmental Protection Agency, through a grant to Rhode Island, assisted in preparation of the State plan. The corporation, which would arrange for construction and operation of facilities, has not been funded.

Tennessee. In early 1974, the State legislature authorized a $10 million resource recovery loan program. Regulations are being drafted for the implementation of this program with technical assistance from the U.S. Environmental Protection Agency.

Vermont. The State solid waste plan calls for mandatory separation of wastes by the householder and the construction of four regional resource recovery facilities. The proposed implementation legislation failed to pass in 1973, but could be reintroduced this year. Chittenden County is planning a pilot implementation of the proposed plan that should be operational in 1976.

Washington. The State is implementing a 6-year, $30 million resource recovery loan and grant program. Grants have been made to several communities to support solid waste planning and small-scale materials recovery operations.

Wisconsin. The State created a Solid Waste Recycling Authority with powers to plan, design, finance, construct, acquire, lease, contract, operate, and maintain resource recovery facilities within designated recycling regions. Three initial recycling regions, encompassing 11 counties, have been established. Funds have been appropriated for the authority's initial costs. The law also establishes bonding authority for construction of facilities. The authority, which is now being formed, is awaiting a Wisconsin Supreme Court decision on technical issues of its legislative charter. Full funding and operation are expected by fall 1975.

Local Activities. Resource recovery systems are operating in five cities around the country (Table 38); another seven are under construction or are in the startup phase; and at least 50 other communities are active in studying or implementing resource recovery systems. A summary of activities in selected communities follows:

Ames, Iowa. The city is building a 200-ton-per-day (TPD) resource recovery facility that will produce a shredded fuel supplement for the city-owned electric utility plant. The plant will also recover ferrous metals, aluminum, and a glass-rich aggregate.

Baltimore, Maryland. With demonstration grant assistance from EPA and a loan from the Maryland Environmental Service, the city is in the startup phase of its 1,000-TPD pyrolysis plant to generate steam for heating downtown buildings. For more information, see Appendix.

TABLE 38

SUMMARY OF IMPLEMENTATIONS OF RECOVERY SYSTEMS, AUGUST 1975

Systems in operation	Systems under construction	Systems selected*	Communities committed†	Communities with expressed interest‡
Braintree, Mass. ¶South Charleston, W.Va. §Franklin, Ohio Nashville, Tenn. §St. Louis, Mo.	Ames, Iowa §Baltimore, Md. Bridgeport, Conn. Chicago, Ill. Milwaukee, Wis. New Orleans, La. Saugus, Mass.	Hempstead, N.Y. Monroe County, N.Y. New Britain, Conn. St. Louis, Mo. (expansion) §San Diego, Calif.	Akron, Ohio Cleveland, Ohio Dade County, Fla. Housatonic Valley, Conn. Lane County, Oreg. Lawrence, Mass. Lexington, Ky. Memphis, Tenn. Minneapolis, Minn. Montgomery County, Ohio New York, N.Y. Onondaga County, N.Y. Portland, Oreg. Seattle, Wash. Westchester County, N.Y. §Wilmington, Del.	Albany, N.Y. Allegheny County, Pa. Auburn, Maine Brevard County, Fla. Boston, Mass. Charlottesville, Va. Chemung County, N.Y. Dallas, Tex. De Kalb County, Ga. Denver, Colo. Detroit, Mich. Dubuque, Iowa Erie County, N.Y. Fairmont, Minn. Grand Rapids, Mich. Hackensack, N.J. Hamilton County, Ohio Hennepin County, Minn. Knoxville, Tenn. Little Rock, Ark. Long Beach, Calif. Los Angeles, Calif. Madison, Wisc. Montgomery County, Md. Middlesex County, N.J. Newark, N.J. Niagara County, N.Y. Peninsula Planning District, Va. Philadelphia, Pa. Phoenix, Ariz. Pinellas County, Fla. Richmond, Va. Salt Lake City, Utah Southeastern Virginia Planning District, Va. Springfield, Mo. Toledo, Ohio Washington, D.C.

*Winner of request for proposals has been selected or a construction contract has been awarded.

† Communities have issued an RFP, have a design study underway, or have made construction funding available.

‡ Includes communities that have completed or are conducting feasibility studies.

§ EPA solid waste demonstration grant.

¶ Large-scale private test facility.

Braintree, Massachusetts. The city has been operating a 240-TPD waterwall incinerator since 1971. It was not until recently that the city developed a market for the steam. In late 1974, a contract was signed for the sale of steam to the Weymouth Art Metal Company.

Bridgeport, Connecticut. Garrett Research and Development Company has been selected to design, construct, and operate a 1,200-TPD resource recovery system, the first facility financed by the Connecticut Resources Recovery Authority. Shredded waste fuel will be sold to United Illuminating Company and used as a supplement to oil to generate electricity.

Chicago, Illinois. A 1,000-TPD shredded fuel system is being constructed by the city. The plant's output will be used as a supplementary fuel by the Commonwealth Edison Company to generate electricity.

Dade County, Florida. With technical assistance from EPA, the county commissioners have evaluated bids from 10 private corporations to build a 3,000-TPD energy recovery facility to produce electricity for sale to Florida Power and Light Co. The county has started negotiations with the two finalists, Black Clawson Company and Universal Oil Products Corporation.

Franklin, Ohio. With demonstration grant support from EPA, the city built a 150-TPD plant that has been recovering paper fiber, ferrous metals, and glass since 1971. For more information, see Appendix.

Hempstead, New York. The town has selected Black Clawson Company to build and operate a 2,000-TPD system to generate electricity for sale to Long Island Lighting Company. The process will involve a wet-pulping technology similar to that used at the Franklin, Ohio, plant.

Lowell, Massachusetts. Until mid-1975, the city was planning to build a system to recover metals and glass from 250 TPD of incinerator residue (the equivalent of 750 TPD of unburned waste) with EPA demonstration grant support. In July, however, the city requested withdrawal from the demonstration following its decision to close down the incinerator rather than undertake very expensive capital improvements for air pollution control. Additional information on the project is provided in the Appendix.

Milwaukee, Wisconsin. The city has signed a contract with Americology, a subsidiary of American Can Company, to build a 1,000-TPD facility to recover shredded fuel, ferrous metals, and corrugated paper. The Wisconsin Electric Power Company has signed a contract with Americology for the purchase of the shredded fuel, which will be fired as a supplement to coal to generate electricity.

Monroe County, New York. The county legislature is negotiating a contract with the Raytheon Corporation to design, supervise construction, startup, and operate for 5 years a 2,000-TPD shredded fuel facility. The fuel will be sold to the Rochester Gas and Electric Company.

Nashville, Tennessee. The Nashville Thermal Transfer Corporation (Thermal) owns and operates a facility to produce steam for heating and cooling buildings in downtown Nashville. The system is designed to burn 720 tons of solid waste per day as the primary fuel; oil or gas can be used in emergencies. No dump fee is charged to the city, which is responsible for ash removal and disposal. As of August 1975, the waste-burning boilers were unable to operate in compliance with the New Source Performance Standards of the Clean Air Act. Thermal has agreed to a compliance plan calling for the installation of electrostatic precipitators to reduce air pollution, replacing the inadequate water spray chambers.

New Britain, Connecticut. Combustion Equipment Associates has been selected to design and build a system to produce 1,800 TPD of "EcoFuel II" (shredded fuel) for the Wallingford Power Plant, which is owned by the city. The shredded waste will be fired as a supplement to fuel oil.

New Orleans, Louisiana. Waste Management, Inc. (WMI), has begun construction of a 650-TPD facility to recover glass, ferrous and nonferrous metals, and paper. The remaining fraction, approximately 80 percent by weight of the incoming waste, will be disposed of on the land. WMI will own and operate the facility. The National Center for Resource Recovery, Inc., designed the plant and will serve the city as technical consultant.

St. Louis, Missouri. With demonstration grant support from EPA, the city of St. Louis has been operating a plant that processes waste for use as a supplementary fuel in the coal-fired boilers of the Union Electric Company. Union Electric has provided the use of its boilers and almost $1 million. Ferrous metals are being sold to the Granite City (Illinois) Steel Company. For more information, see Appendix.

St. Louis Area. Because of the success of the EPA demonstration, the Union Electric Company is designing and ordering equipment for a $70 million system to process 8,000 tons of solid waste per day from the Greater St. Louis area. Fuel will be recovered and used as a supplement to coal in several boilers at two plants.

San Diego County, California. With demonstration grant support from EPA, the county is going to build a 200-TPD pyrolysis system designed by Garrett Research and Development Company. The liquid fuel produced will be used as a supplementary fuel by San Diego Gas and Electric Company. For more information, see Appendix.

Saugus, Massachusetts. RESCO, Inc., a joint venture of DeMatteo Construction Company and Wheelabrator-Frye, Inc., is constructing a 1,200-TPD waterwall incinerator. The steam generated will be sold to the General Electric Company plant in Lynn, Massachusetts. Construction is scheduled to be completed in mid-1975.

South Charleston, West Virginia. Union Carbide Corporation owns and operates a 200-TPD test facility that produces fuel gas using a pyrolysis process.

Wilmington, Delaware. The State, with solid waste demonstration grant support from EPA, is preparing to build a 500-TPD facility to produce shredded fuel, humus, metals, and glass. The fuel will be fired as a supplement to oil in the boilers of the Delmarva Power & Light Company. The facility will accept sewage sludge and selected industrial wastes in addition to residential and commercial solid waste. For more information, see Appendix.

REFERENCES

1. Hopper, R.E. A nationwide survey of resource recovery activities. Environmental Protection Publication SW-142. [Washington], U.S. Environmental Protection Agency, Jan. 1975. 74 p. [Updated periodically.]

APPENDIX

DESCRIPTION OF SIX EPA-SUPPORTED RESOURCE RECOVERY TECHNOLOGY DEMONSTRATIONS

SHREDDED, CLASSIFIED WASTE AS A COAL SUBSTITUTE–ST. LOUIS, MISSOURI

The city of St. Louis operates facilities to separate shredded organic material from residential solid waste for use as fuel. The fuel is burned with coal in electric utility boilers of the Union Electric Company. Ferrous metal is also recovered and sold to a steelmill. Midwest Research Institute is under contract with EPA to conduct an independent evaluation of the project.

The time and cost schedule for the demonstration is presented in Table 39.

TABLE 39
TIME AND COST SCHEDULE,
ST. LOUIS PROJECT

Activity	Time period	Total cost	Federal share of cost
Design and construction	July 1970 to April 1972	$3,288,544	$2,180,026
Operation and evaluation	May 1972 to June 1975*	600,000	400,000
Total		$3,888,544†	$2,580,026

*The project has been extended for additional tests.

†Union Electric Company is to provide $950,000 and the city of St. Louis the remaining $358,518 of the non-Federal share. In addition, EPA is spending about $750,000 to evaluate the project.

The Processing System

The system currently accepts solid waste from residential sources. It was designed to exclude oversized bulky wastes, such as tires, appliances, furniture, engine blocks, and land-clearing and demolition wastes. This limitation is a function of the capacity of the shredders and the fuel quality objective.

The system was designed to handle 325 tons of waste in one 8-hour processing shift and three 8-hour fuel-firing shifts. Raw solid waste is discharged from packer-type collection trucks onto the floor of the receiving building. Front-end loaders push the waste to a receiving belt conveyor. From the receiving conveyor, the waste is transferred to the hammermill, a shredding device.

Shredding reduces residential raw waste to particles that are relatively uniform in size and therefore easier to separate mechanically into salable components. It also reduces odors and facilitates handling.

In the St. Louis shredder, 30 large metal hammers swing around a horizontal shaft, grinding the waste against an iron grate until the particles are small enough to drop through the grate openings. The design calls for a nominal particle size of 1½ inches. Preliminary data show that over 90 percent by weight of the incoming waste is reduced to particles not greater than 1 inch in any dimension.

Single-stage milling (all shredding in one pass through the shredder) was selected for the prototype system to minimize capital costs. For future applications, however, experts recommend a two-stage shredding operation, with air classification between the two stages. The first shredding would reduce the waste to a particle size of about 4 to 8 inches. After removal of the heavier materials by the air classifier, the second shredding would reduce the particle size of the light fraction to 1 or 2 inches.

In the present St. Louis system the shredded waste is conveyed from the hammermill to the air classifier. The air classifier separates the heavier, mostly noncombustible particles from the lighter ones in a vertical chute where a column of air blowing upward carries the lighter materials to the top. The heavier materials drop to the bottom. By varying the air velocity and the cross-sectional area of the chute, the percentage split between heavy and light fractions can be controlled. The St. Louis air classifier is operated to permit 75 to 80 percent of the shredded waste to be separated into the light fraction for use as fuel.

The light fraction is composed of paper, light cardboard and plastics, textiles, light food wastes, and other organics. There is also a small percentage of light noncombustibles like aluminum foil in this fraction. It also contains small particles of heavier materials, such as pulverized glass, that stick to pieces of organic material.

The heavy fraction contains ferrous and nonferrous metals, glass, dirt, and other noncombustibles. Certain heavier combustible materials, such as citrus fruit rinds and heavier pieces of cardboard, plastics, woodchips, and rubber, also drop into the heavy fraction.

Removal of both the combustible and noncombustible heavy materials from the waste produces three benefits: an increase in the heating value of the waste as fuel, an increase in the transportability of the fuel through the pneumatic pipelines, and a decrease in the boiler's bottom ash. The presence of the small bits of glass and other noncombustible materials remaining in the fuel does not have a significant effect.

The light materials are carried pneumatically from the separation chute to the cyclone separator, where they are removed from the air stream and allowed to fall onto the conveyor leading to the storage bin.

The heavy fraction is passed under a magnetic belt to extract the ferrous metals, which are then densified in a nuggetizer. After passing under a magnetic drum for a final cleanup, the ferrous metals are transported to the Granite City Steel Company where they are used in a blast furnace. The nonmagnetic materials are hauled away to be landfilled.

By recovering fuel and ferrous metal, the city of St. Louis has reduced its landfill volume requirements by 95 percent of the solid waste processed.

At scheduled intervals, quantities of the solid waste fuel are removed from the storage bin at the processing plant and loaded onto trailer trucks for the 18-mile trip to the powerplant. At the powerplant the fuel is unloaded into a receiving bin, which is in turn unloaded continuously into a pneumatic pipeline transport system. These pneumatic pipelines discharge the fuel into a surge bin. The surge bin uses four drag-chain unloading conveyors to move the solid waste fuel to four separate feeders that introduce the supplementary fuel into the pneumatic pipeline system. The pipelines, each about 700 feet long, blow the fuel to firing ports in each corner of the boiler furnace.

The ownership and operating responsibility of the city ends at the point where the city's pneumatic pipelines discharge the fuel into the surge bin owned by the utility.

Operating Experience

Until September 1974, the processing plant operated at about 20 percent of design capacity. Downtime was caused by a variety of factors, including waste collection stoppages resulting from strikes and bad weather, mechanical problems with almost every piece of equipment in the system, and system modifications. Since September 1974, however, the system has operated consistently at 150 to 300 tons per day, 5 days per week, depending upon the requirements of the testing and evaluation program and the availability of the boilers.

Boiler Modification and Operation

Two identical boilers at Union Electric Company's Meramec Plant near St. Louis have been modified to burn prepared solid waste. They are 125 megawatt tangentially suspension-fired boilers that were originally designed to burn pulverized coal or gas. There are now four coal-firing, one solid-waste-firing, and five gas-firing ports in each corner of each boiler.

Other than installing a solid-waste firing port in each corner of the furnace, no modifications to the boilers were made. The prepared solid waste is burned in suspension in the same flame pattern as the pulverized coal.

As is typical of large utility boilers, the furnaces have no grates. Fuels are burned in suspension at temperatures of 2,400 F to 2,600 F. The retention time of 1 to 2 seconds in suspension is not long enough for the heavier particles of combustible materials to be consumed, and they fall to the bottom ash hopper along with the noncombustible materials.

The two boilers are 20 years old and are small compared to newer units in the Union Electric Company system. They are of modern reheat design, however, and burn 56.5 tons of Illinois coal per hour at rated load.

At rated load, the quantity of solid waste burned in each boiler is equivalent in heating value to 10 percent of the coal and amounts to about 12.5 tons per hour, or 300 tons per 24-hour day. Solid waste is fired 24 hours per day, but only 5 days per week, because city residential solid waste collections are scheduled on a 5-day-per-week basis.

The boiler operators and shift superintendents report that solid waste firing has had no discernible effect on the boiler furnace or convection passes. (Convection passes are hot gas passages containing heat-transfer surfaces between the boiler furnace and the air pollution control equipment.) Frequent and sudden interruptions of the solid waste feed have not required any change in operating techniques. Existing boiler combustion controls easily accommodate the variations in solid waste quantity and quality by varying the amount of pulverized coal fired into the boiler.

The boiler's efficiency or power-producing capability when firing solid waste in combination with coal is reduced slightly compared to "coal only" performance.

Firing solid waste significantly increases the quantity of bottom ash produced, requiring the boiler operators to remove the ash from the hopper more frequently than when coal is fired alone.

Air Emissions from Combined Firing of Waste and Coal

Air emission tests were performed independently by Midwest Research Institute (MRI) from October through December 1973 as part of EPA's comprehensive evaluation of the project. The Union Electric Company (UE) also performed air emission tests during the same period. MRI employed the EPA-approved testing method to measure particulate and gaseous emissions. Union Electric employed the American Society of Mechanical Engineers testing method to measure particulates only.

The results of the MRI tests are summarized in the *St. Louis/Union Electric Refuse Firing Demonstration Air Pollution Test Report*, September 1974, available from the National Technical Information Service, U.S. Department of Commerce.

From the MRI tests it appears that gaseous emissions (sulfur oxides, nitrogen oxides, hydrogen chlorides, and mercury vapor) are not significantly affected by combined firing of waste and coal.

Both MRI and UE tests found that particulate levels per cubic foot of exhaust gas at the inlet to the air pollution control device (the electrostatic precipitators) were not affected by combined firing; however, total inlet particulate levels did increase because of increases in the stack gas flowrate.

The MRI tests did not find an increase in particulate emissions when solid waste was combined with coal. The UE tests, however, did find an increase in such emissions. Therefore, the report is not conclusive on this subject. Also, there is evidence to indicate that neither set of tests provides an optimum representation of combined firing of solid waste and coal. It appears that the electrostatic precipitator was not properly conditioned prior to the tests and could have been tuned for better particulate collection performance.

The report recommends that further tests be conducted to complete the characterization of particulate emissions and to support the development of Federal and State air emission control standards. In response to this recommendation, a second series of tests, conducted independently by EPA and UE, were initiated in late 1974 and are expected to be completed by late 1975.

Economics

The cost of the facilities was about $3 million when they were constructed in 1971. Gross operation and maintenance costs (excluding amortization and interest) for the city and Union Electric Company, based on operating experience from July 1972 to November 1974, are $5.90 per ton of solid waste processed, and $8.50 per ton of solid waste fuel burned, respectively. During this time, the facilities operated at about 30 percent of the 5-day-week single-shift capacity. Consequently, the unit operating costs could be expected to be substantially lower when the plant is operated at design capacity.

However, a higher capital investment would probably be required to achieve greater reliability.

These figures are not at all representative of the cost of a supplementary fuel system to be built elsewhere. In addition to the effect of inflation (about 15 to 20 percent per year for many construction materials), site-specific factors will dictate the economic feasibility of a system. The cost would range from as little as $5 or $8 per ton, to a prohibitively high figure. The major site-specific factors are: characteristics of waste fuel market (distance to boiler, boiler size, load factor, air pollution control equipment, price of primary fuel); characteristics of markets for recovered metals and glass (distance, price, stability, quantity in waste stream); plant capacity (waste available, equipment redundancy, operating shifts per day, operating days per year); method of financing (public or private capital); and the cost of alternative means of waste disposal.

A more comprehensive discussion of the economics of resource recovery systems is presented in Chapter 5.

PYROLYSIS FOR STEAM GENERATION– BALTIMORE, MARYLAND

With the aid of an EPA demonstration grant, the city of Baltimore owns and operates a 1,000-ton-per-day solid waste pyrolysis plant developed by Monsanto Enviro-Chem Systems, Inc. The system was designed and constructed by Monsanto under a turnkey contract with money-back performance guarantee provisions. Monsanto has guaranteed plant availability at 85 percent, particulate emissions to meet local and Federal standards, and the putrescible content of the residue to be less than 0.2 percent. Monsanto's maximum payback liability is $4 million, about 25 percent of the contract price. The time and cost schedule for design, construction, operation, and evaluation is given in Table 40.

The plant is designed to handle mixed municipal solid waste, including tires and white goods. All incoming wastes are shredded to a 4-inch particle size and then conveyed to a rotary pyrolysis kiln. About 7.1 gallons of No. 2 fuel oil per incoming ton of waste is combusted to provide heat for the pyrolysis reaction. In addition, about 40 percent of the amount of air theoretically required for complete combustion is added to the reactor to allow some of the pyrolysis gases to combust and add additional heat to the unit. The remaining pyrolysis gases leave the kiln and are then combusted in an afterburner. The hot afterburner exhaust gases pass through waste heat boilers that generate 200,000 pounds of steam per hour for sale to the Baltimore Gas and Electric Company (Table 41). The steam is used for downtown heating and cooling. Boiler exhaust gases are scrubbed, dehumidified, and released to the atmosphere.

Although the system uses about 7.1 gallons of No. 2 fuel oil per ton of incoming waste, the steam generated from each ton of incoming waste will conserve 39.1 gallons of fuel oil, for a net savings of 32 gallons.

The pyrolysis residue is water-quenched, and ferrous metals are separated for recycling by Metal Cleaning and Processing Company, Inc. Water flotation and screening processes separate the char residue, which is landfilled, from a glassy fraction which will be used as aggregate for city asphalt street construction. Sixteen tons of char with 50 percent moisture is produced for every 100 tons of solid waste input. Air emissions are monitored and controlled to meet local and Federal standards; no wastewater is discharged.

The projected economics for this system, based on February 1974 data, are summarized in Table 42.

PYROLYSIS TO PRODUCE LIQUID FUEL– SAN DIEGO COUNTY, CALIFORNIA

San Diego County will build and operate a 200-ton-per-day pyrolysis plant with the aid of an EPA demonstration grant. The time and cost schedule is presented in Table 43.

The key component of this plant will be a flash pyrolysis unit developed by the Garrett Research and Development Company. Mixed municipal solid waste will be shredded coarsely to a 3-inch particle size and then separated mechanically into two fractions: a "light" fraction consisting mostly of paper and plastic and a "heavy" fraction consisting of glass, metals, wood, and stones.

The light material will be dried and shredded again, to a very fine particle size (practically a powder) and then pyrolyzed at a temperature of about 900 F. This process produces a gas, which is condensed into an oil-like liquid with a heat value

TABLE 40
TIME AND COST SCHEDULE, BALTIMORE PROJECT

Activity	Time period	Total cost*	Federal share of cost
Design and construction	January 1973 to December 1974	$16,177,000	$6,000,000
Shakedown, operation, and evaluation†	January 1975 to December 1976		

*Baltimore is to provide $6,177,000 and Maryland Environmental Services is to provide $4 million of the non-Federal share.
†Length of shakedown period and cost of possible plant modifications cannot be estimated accurately at this time.

TABLE 41
ANTICIPATED OUTPUTS AND MARKET VALUES, BALTIMORE PROJECT

Product	Tons per 100 tons of waste input	Market value per ton sold
Steam	240	$ 4.66
Ferrous metal	7	22.00
Glassy aggregate	17	2.35

about 75 percent that of No. 6 fuel oil. It will be used as supplementary fuel in an existing San Diego Gas and Electric Company boiler.

From the heavy fraction, ferrous metals will be separated by an electromagnet and glass will be separated as a mixed-color glass cullet by a froth flotation process. The anticipated outputs and prices are summarized in Table 44.

When operating at capacity (200 tons per day), 11 tons of char as well as 32 tons of other residuals will require landfilling each day. Exhaust gases will be monitored and controlled to meet local and Federal standards, and wastewater will be discharged into a sanitary sewer.

This system requires no external fuel and produces a storable, transportable fuel that should have good national marketability.

The projected economics of the system are summarized in Table 45.

PROCESSED WASTE AS A FUEL OIL SUBSTITUTE–STATE OF DELAWARE

With the aid of an EPA demonstration grant, the State of Delaware will enter into a full-service

TABLE 42
PROJECTED SYSTEM ECONOMICS FOR BALTIMORE PROJECT, BASED ON FEBRUARY 1974 DATA*

Item	Value
Capital investment†	$20,000,000
Annual cost:	
Amortization and interest	1,720,500
Operation and maintenance	2,356,000
Total annual cost	$ 4,076,500
Costs and revenues per input ton of solid waste:	
Cost before revenue	$13.15
Revenues:	
Steam	11.18
Ferrous metal	1.55
Glassy aggregate	.40
Total revenues	13.13
Net cost	$ 0.02‡

*Based on a 1,000-ton-per-day operation in which 310,000 tons of raw solid waste are throughput per year.

†Using February 1974 dollars, $20 million of capital is required.

‡Because these are estimates based only on pilot plant experience, the actual costs and revenues may be significantly different.

contract with a single company that will design, construct, and operate a resource recovery facility to be located in Wilmington. The contractor will be selected competitively after proposals are solicited. The contractor will guarantee plant performance and capital, operating, and maintenance costs.

The plant will be designed to process daily 485 tons of municipal solid waste, 15 tons of industrial

TABLE 43

TIME AND COST SCHEDULE, SAN DIEGO PROJECT

Activity	Time period	Total cost	Federal share of cost
Design	December 1974 to April 1975	$7,423,244	$3,562,710
Construction	August 1975 to May 1976		
Operation and evaluation	June 1976 to December 1977	1,457,795	–
Total		$8,881,039*	$3,562,710

*San Diego County is to provide $1,817,329, and Garrett Research and Development Company is to provide $3,500,000.

TABLE 44

ANTICIPATED OUTPUTS AND PRICES,
SAN DIEGO PROJECT
(200 TPD PLANT)

Product	Quantity per day	Price
Oil	172 barrels	$4.33 per barrel
Ferrous metal	23.7 tons	18.20 per ton
Glass	10.4 tons	6.40 per ton

TABLE 45

PROJECTED SYSTEM ECONOMICS, SAN DIEGO PROJECT*

Capital investment	$6,344,000
Annual costs:	
Amortization and interest	553,069
Operation and maintenance	916,351
Total annual cost	$1,469,420
Costs and revenues per input ton of solid waste:	
Cost before revenue	$ 23.70
Revenues:	
Oil	3.80
Ferrous metal	2.30
Glass	.40
Total revenues	6.50
Net cost	†$ 17.20

*Based on a 200-ton-per-day operation in which 62,050 tons of raw solid waste are processed per year.

†Because these are estimates based only on pilot plant experience, the actual costs and revenues may be significantly different.

waste, and 230 tons of digested sewage sludge containing 8 percent solids. Incoming municipal solid waste will be shredded to a 6- to 8-inch particle size. The shredded waste will be air-classified into two fractions: a "light" combustible waste fraction containing about 60 to 75 percent of the incoming waste and a "heavy" waste fraction containing metals, glass, wood, heavy plastics, textiles, rubber, and rocks.

The light fraction will be shredded again to a 1-inch particle size. Most of the light fraction will then be sent directly to Delmarva Power and Light Company for use as supplemental fuel in existing oil-fired boilers. The remaining light fraction will be mixed in aerobic digestors with partially dewatered sewage sludge for use as compost or supplemental powerplant fuel, or both, depending upon market conditions.

The heavy fraction will be processed to remove ferrous metals for recycling. The remaining heavy materials will be mixed with selected industrial wastes and pyrolyzed. Heat from the pyrolysis gases will be used to help dewater the sewage sludge. Aluminum and glass will be recovered from the pyrolysis residue. The remaining residues will be landfilled (about 10 percent by weight of the incoming waste).

The State of Delaware has projected the economics of the system based on a preliminary design by Black, Crow, and Eidsness, Inc. EPA has used these projections as a basis for the updated estimates given in Tables 46 and 47. The actual costs of the system will not be known until the fixed price contract is signed in early 1976.

TABLE 46
PROJECTED SYSTEM ECONOMICS WILMINGTON PROJECT*

Item	Value
Capital investment†	$25 million
Annual costs:	
Amortization and interest‡	2.2 million
Operation and maintenance§	1.7 million
Total annual costs	$ 3.9 million
Costs and revenues per input ton of solid waste:¶	
Cost before revenue	$29.60
Revenues:**	
Humus (compost)	1.10
Solid waste fuel	10.00
Ferrous metal	2.80
Nonferrous metal	.80
Glass	.35
Paper	.10
Sludge disposal credit	1.45
Total revenues	16.60
Net cost	$ 13.00

*These are rough projections by EPA based on earlier estimates developed by Black, Crow and Eidsness, Inc., for the State of Delaware.

†Using 1977 dollars, calculated by escalating 1974 projections at 15 percent per year; includes projected cost of processing plant, fuel transport facilities, fuel receiving and firing facilities, boiler modifications, and air pollution control equipment modifications to the utility's boiler.

‡Assumes capital paid back at 6 percent interest over 20 years.

§Using 1979 dollars, calculated by escalating 1974 projections by 10 percent per year.

¶130,000 tons of waste are to be processed per year.

**Using 1974 dollars.

TABLE 47
ANTICIPATED OUTPUTS AND MARKET VALUES, WILMINGTON PROJECT*

Product	Tons per day	Market value per ton sold
Humus (compost)	38 (dry)	$ 14.70
Solid waste fuel	305	16.40†
Ferrous metal	35.5	40.00
Nonferrous metal	2	200.00
Glass	25	7.00
Paper	5	10.00
Sludge disposal	18 (dry)	40.00

*Estimates by EPA based on earlier estimates by Black, Crow and Eidsness, Inc., for the State of Delaware; uses 1974 dollars.

†Assumes fuel oil costs $2.00 per million Btu, and that solid waste fuel has a heat value of 5,000 Btu/lb, or 10 million Btu/ton. Value of fuel is discounted to reflect the boiler efficiency loss when firing waste. Efficiency loss is assumed to be 2 percent (a conservative figure, based on EPA conversations with boiler manufacturers).

The total cost of the project is estimated to be about $28 million, with the EPA grant covering $9 million of the costs (see Table 48 for cost and time schedule). If the full-service contract is initiated on schedule by August 1976, the system should be fully operational by April 1980.

WET PULPING FOR MATERIALS RECOVERY – FRANKLIN, OHIO

The objective of this project is to demonstrate a refuse disposal and resource recovery system capable of processing municipal refuse and producing metals, color-sorted glass, and paper fiber in a recyclable form. Nonrecoverable combustible materials are incinerated in a fluidized bed reactor. Noncombustible rejects are landfilled. The time and cost schedule for design, construction, and operation is given in Table 49.

The total system, with a design capacity of 150 tons per 24-hour day, contains three separate subsystems: a processing and disposal system for solid waste and sewage sludge with recovery of ferrous metal, a glass and aluminum recovery system, and a paper fiber recovery system.

The disposal system consists primarily of a wet pulper ("hydrapulper"), a liquid cyclone, and a fluidized bed incinerator. Ferrous metal is recovered through magnetic separation and sold as scrap to a steelmill.

The glass and aluminum subsystem uses a complex series of mechanical screening and classifying operations to extract a glass-rich stream and an aluminum-rich stream from the heavier materials in the waste. Optical sorters separate the glass into flint, green, and amber particles for use in making new bottles.

The fiber recovery subsystem recovers paper fiber from the lighter combustible materials in the waste stream. Fiber is recovered through the use of several screening and cleaning operations. It is then pumped in slurry form to a nearby papermill through an underground pipe. The fiber is used in making felt paper for asphalt roofing shingles.

TABLE 48
TIME AND COST SCHEDULE, WILMINGTON PROJECT

Activity	Time period	Total cost	Federal share of cost
Design and construction	August 1976 to August 1979	$25,000,000	$6,755,000
Startup	August 1979 to April 1980	328,000	245,000
Operation and evaluation	April 1980 to April 1981	2,700,000	2,000,000
Total		$28,028,000	$9,000,000

TABLE 49
TIME AND COST SCHEDULE, FRANKLIN PROJECT

Phase and activity	Time period	Total cost	Federal share of cost
Hydraposal and fiber recovery systems:			
Design	March 1969 to February 1970	$ 165,000	$ 110,000
Construction	March 1970 to June 1971	1,970,000	1,300,000
Operation and evaluation	June 1971 to August 1972	500,000	350,000
Subtotal		2,635,000	1,760,000
Glass and Aluminum Recovery System:			
Design	July 1971 to May 1972	20,000	60,000
Construction	May 1972 to July 1973	360,000	257,000
Operation and evaluation	July 1973 to February 1976	90,000	77,000
Subtotal		470,000	394,000
Total		$3,105,000*	$2,154,000

*Approximate non-Federal contributions: the city of Franklin, $500,000; the Black Clawson Company, $200,000; and the Glass Container Manufacturers Institute, $150,000.

System outputs are shown in Table 50.

All combustible residues, as well as sludge from an adjacent sewage treatment plant, are disposed of in the fluidized bed incinerator.

All noncombustible rejects (approximately 10 percent by weight of the total incoming wastes) are disposed of in a small sanitary landfill adjacent to the plant. Air emissions from the fluid bed incinerator have been found to be below the Federal standards. All water effluents from the plant are discharged into the adjacent sewage treatment plant.

TABLE 50
PRODUCT OUTPUTS AND PRICES, FRANKLIN PROJECT

Product	Tons per 100 tons of waste input	Price per ton sold
Ferrous metal	9	$ 25
Paper fiber	20	42
Glass (color-sorted)	4	20
Aluminum	.3	200

The projected system economics for a 500-ton-per-day facility are summarized in Table 51.

TABLE 51
PROJECTED ECONOMICS FOR 500-TON-PER-DAY FRANKLIN-TYPE SYSTEM*

Item	Value
Capital investment	$10,600,000
Annual costs:	
Amortization and interest†	1,350,000
Operations and maintenance	1,286,868
Total annual costs	$ 2,636,868
Costs and revenues per input ton of solid waste:	
Cost before revenue	$ 20.42
Revenues: ‡	
Ferrous metal	2.40
Paper fiber	8.06
Sewage sludge disposal credit	1.75
Total revenues	12.21
Net cost	$ 8.21

*Based on a three-shift operation in which 150,000 tons of raw solid waste are throughput per year. The Franklin plant processes approximately 50 tons per day.

†Based on 20-year depreciation.

‡Does not include glass and aluminum recovery.

MATERIALS RECOVERY FROM INCINERATOR RESIDUE–LOWELL, MASSACHUSETTS

In this project, the city of Lowell was to build a full-size processing plant capable of recovering materials from 250 tons of incinerator residue, which represents about 750 tons of raw waste, each 8-hour day (Table 52). In July 1975, however, the city requested withdrawal from the demonstration, and the project was therefore terminated. The reason for the withdrawal was that the city decided to close down their incinerator rather than undertake very expensive capital improvements for air pollution control.

The primary objective of the project was to demonstrate the technical and economic feasibility of a mechanical separation system for recovering metals and glass from the noncombustible portion of solid wastes. Initially, these products were to be recovered from incinerator residues, but the system was also designed to handle noncombustible solid wastes that have been separated from the combustible fraction by air classification or some other means.

The design for the plant was prepared by the Raytheon Company using the system piloted by the U.S. Bureau of Mines at College Park, Maryland. The system uses a series of screens, shredders, classifiers, and other ore-processing equipment to extract steel, nonferrous metals, and glass from the incinerator residue. The project plans for Lowell called for recovery of more than 40,000 tons of products annually which would result in revenues of some $700,000 a year (Tables 53 and 54). Depending on the level of burnout in the incinerator residue, about 5 tons of solid residue per 100 tons of incinerator residue input would be landfilled. No gaseous pollutants would be emitted from the processing plant, and process water would be treated in the plant before being discharged into the city's sanitary sewer system.

TABLE 52
TIME AND COST SCHEDULE, LOWELL PROJECT (CANCELLED JULY 1975)

Activity	Time period	Total cost*	Federal share of cost
Design, construction management	February 1973–December 1974	$ 798,000	$ 325,000
Construction	January 1975–March 1976	3,321,000	1,434,000
Operation and evaluation	April 1976–March 1977	734,000	625,000
Total		$4,853,000	$2,384,000

*The State of Massachusetts was to provide a total of $615,000, and the city of Lowell, $1,854,000 plus $180,000 in land value for the facility site.

TABLE 53

ESTIMATED SYSTEM OUTPUTS AND PRICES, LOWELL PROJECT

Product	Tons per 100 tons of input*	Price per ton sold
Ferrous metal	30	$ 33
Aluminum	2	250
Copper/zinc	1	330
Glass	30	23
Aggregate	32	2

*Incinerator residue.

TABLE 54

PROJECTED SYSTEM ECONOMICS, LOWELL PROJECT*

Item	Value
Capital investment	$4,119,000
Annual costs:	
Amortization and interest	424,000
Operation and maintenance	734,000
Total annual costs	$1,158,000
Costs and revenues per ton of input (incinerator residue):	
Cost before revenue	$ 17.80
Revenues:	
Ferrous metal	4.80
Aluminum	3.12
Copper/zinc	2.08
Glass	6.75
Aggregate	.50
Total revenues	17.25
Net cost	$ 0.55

*Based on a one-shift, 250-ton-per-day operation in which 65,000 tons of incinerator residue are throughput per year.

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